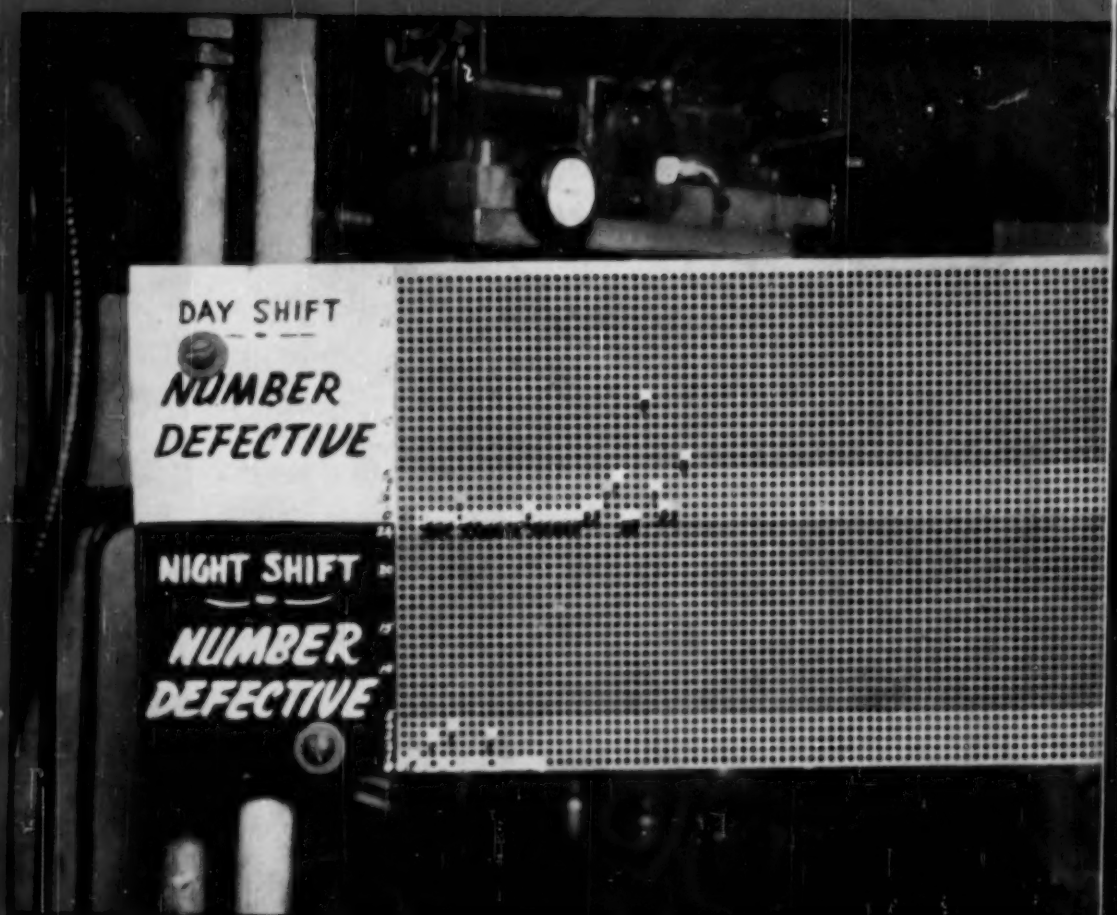
Industrial QUALITY CONTROL

Vol. XII, No. 4
OCTOBER, 1955



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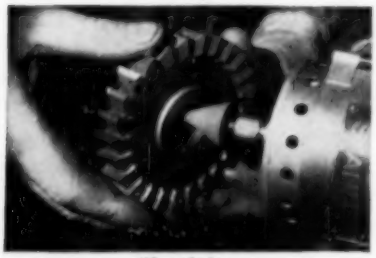

Chamfering

Cleaning a casting

Deburring a slot

What's New?

ROY A. WYLIE, *Editor*

Baldwin - Lima - Hamilton Corp., Philadelphia 42, Pa., announce a new Baldwin SR-4 bonded resistance wire strain gage with flat grid, fine pitch, and Bakelite base. Type ABF-7 with ¼ inch grid length may be used in place of wrap-around type gages of short grid length. Type EBDG-7T+ is a self-compensated gage of ¼ inch grid length for use on titanium (TRC-70 or TRC-130 or equal.) Temperature range is plus 50 to 250 degrees F. Type EBDF-13Q+ is a self-compensated gage of ⅜ inch grid length for minimum response to temperatures between plus 50 and 250 degrees F when cemented to quartz. Bonded to unrestrained members of other material, it would measure thermal expansion stress when temperature-cycled. Alternate 13T+ type gages for titanium and 13Q— and 7Q— for quartz are also available.

* * *

A new light-weight visual tachometer called "Visutac" has been announced by **Boulin Instrument Corp.**, 65 Madison Avenue, New York, N. Y. The new device operates by spring-wound mechanism which stops motion by a stroboscopic principle. It is a simple, accurate, mechanical instrument slightly larger than a baseball and weighs only 11 ounces. Applications include accurate measurement of the speed of rotating objects having no accessible shaft ends such as drills, mixers and governors. It may also be used for fans, blowers, pumps, propellers and turbines. Oscillating and vibrating objects may also be studied with Visutac. Two basic ranges are available: 500 to 8,000 and 1,000 to 16,000 RPM-VPM. Accuracy is within two percent above the first 15 percent of either scale. No accessories are required and the unit can be wound, focused, synchronized to stop motion and read at leisure.

* * *

Federal Products Corp., 1144 Eddy Street, Providence 1, R. I., have announced a new series of adjustable dial hole gages which feature an entirely new solution to the problem of accurate centralization of the gage

(continued on page 37)

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OUR COVER

This month's cover picture, courtesy Thomas & Betts Co., Inc., shows a unique system of quality control in operation. The picture telling story of "Cribbage Board Quality Control" is the feature of this month's "From the Scrap Box", pages 24-25.

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ASQC and Operations Research

PAUL S. OLMSTEAD
Chairman, Operations Research Committee, ASQC

APPOINTMENT OF THE OPERATIONS RESEARCH COMMITTEE

The relation of Operations Research to Quality Control first came up for discussion in the Executive Committee of ASQC in 1951. This was the year in which an article on Operations Research appeared in *Fortune*, Morse and Kimball's book was published, and a brochure relating to nonmilitary applications was made available by the Committee on Operations Research of the National Research Council. After due deliberation, it was decided to appoint a committee to explore the subject and make recommendation to the Executive Committee. The following were appointed to this committee:

Frederick J. Halton, Jr.
Dorian Shainin
Wade R. Weaver
Samuel S. Wilks
William J. Youden
Paul S. Olmstead, Chairman

During the first committee meeting, at the Syracuse Convention in May 1952, Hugh M. Smallwood was also made a member. To date, the only changes in committee membership have been the loss of Dr. Smallwood by death in 1953 and the recent appointment of W. E. Andrus, Jr.

CONVENTION PROGRAMS ON OPERATIONS RESEARCH

Interest in Operations Research on the part of ASQC members was stimulated by an article on "Operations Research in Business and Industry" by Russell L. Ackoff, published in the May 1952 issue of *Industrial Quality Control*. As a result, the committee concluded that future convention programs should include sessions on the subject. Since that time, arrangement of such programs has been the major activity of the committee.

The first program was exploratory. Its aim was to examine the question:

What is Operations Research?

The two sessions presented at the 1953 Convention at Philadephia were as follows:

"Industrial Applications of Operations Research," J. B. Lathrop, Arthur D. Little, Inc., and

"A Panel Discussion on the Place of Operations Research versus Quality Control," J. B. Lathrop, Arthur D. Little, Inc.; A. W. Swan, Courtaulds, Ltd.; W. R. Weaver, Republic Steel Corporation; and Samuel S. Wilks, Princeton University.

The article by Mr. Lathrop is included in this issue.

Many of those who attended these sessions came away with the impression that Quality Control often includes some Operations Research. Thus, it became apparent that the next program should attempt to bring out some of the differences, particularly those that Quality Control people might find useful in their work. With this in mind, the 1954 program for the St. Louis Convention related to the subject:

The Concepts of OR and QC.

The following articles were presented:

"OR Concepts Useful in QC," H. O. Davidson, Operations Research Office, Johns Hopkins University, and

"QC Concepts Useful in OR," P. S. Olmstead, Bell Telephone Laboratories.

In addition to these articles, which are included in this issue, attention should be directed to articles by Leroy A. Brothers, "Operations Analysis in the United States Air Force," and M. L. Hurni, "Observations on Operations Research." They appeared in the February and August 1954 issues of the *Journal of the Operations Research Society of America*. These explain the concepts of OR from other viewpoints.

The choice of a topic for the OR sessions for the 1955 Convention in New York was suggested in part by the appearance of a new book, *Design for Decision*, by I. Bross. This book refers to both OR and QC processes as examples of design for decision. In view of this, the topic chosen was:

Common Features of OR and QC.

The following program resulted:

"Design for Decision," I. Bross, Cornell University Medical Center, and

"Integrating Operations Research into a Business," H. D. Mills, General Electric Company.

It is quite obvious that QC people have the problem of integrating Quality Control into a business and, therefore, the second article is also pertinent to the chosen topic. These two articles will appear in subsequent issues of *Industrial Quality Control*.

THE PRESENT STATUS OF *OR* IN ASQC

These programs have helped orient OR with respect to QC. Many of the original articles on OR had pictured it as a problem solving technique for complex situations. Particular emphasis had been placed on the use of the "feedback principle" and "team research," which seemed to be new terms for activities long accepted as necessary in any QC investigation. However, the mathematics used was often more complex than that required for most QC work. Nevertheless, many of the examples that were published were scarcely distinguishable from QC. The most noticeable difference was associated with taking action. This is normally included in QC but OR only presents its findings to others for their action.

More recent articles suggest that OR should include an "Operation of Statistical Control" in essentially the same manner as it is used in QC. These articles also suggest that maximum value, or profit, is the primary objective of OR. In situations where value or profit may be expressed in physical terms, OR may become identical to QC. Where it cannot, OR may approach QC applied to dollar situations.

One instance where OR considerations may be important in QC work is for estimating performance after proposed modifications in existing processes or designs. Basically, it is an OR problem to determine what characteristics of a product must be controlled in order to provide the kind of quality desired. Hence, it is very apparent that Quality Control in the broad sense must include a great deal of Operations Research. The Operations Research Committee

will continue to take this into account in planning its future programs.

SUPPLEMENTARY NOTE

After the above had been submitted, the Editor of *Industrial Quality Control* brought my attention to the article by D. F. Boyd in the May issue. Readers will note that the conclusions of this article, "Operations Research in Industry," are in substantial accord with the ideas expressed here. He mentions, for instance, that "Dr. Shewhart's work was Operations Research in its highest sense." On this basis, a great deal of what we accept as development of Quality Control Theory may be classified by others as Research on the Operation of maximizing Quality. Conversely, it is likely that we will find use for a great deal that is being published as Operations Research in our development of Quality Control Theory.

Industrial Applications Of Operations Research

JOHN B. LATHROP

Arthur D. Little, Inc., Cambridge, Mass.

Most of you are interested in the development of a scientific basis for controlling the quality of industrial production. You may also be interested, then, in operations research, which applies the methods of scientific research to control and decision problems in many areas of business and industrial management.

This article will outline briefly how operations research began, what it is and how it works, with some examples of its use. We will also touch upon what it adds to present management techniques, and some recent developments in the field.

HOW OPERATIONS RESEARCH BEGAN

Organized operations research was a war baby, and commenced with the formation of groups of scientists to analyze combat data in wartime, in order to determine the effectiveness of selected military operations, and to devise means for improving the use of weapons and weapons systems. The techniques of scientific research were applied to many operating problems never before approached in this manner, many of which were widely held to be unsusceptible to scientific or quantitative methods of attack.

In anti-submarine warfare, in connection with the terrific problem of finding enemy submarines at sea, OR isolated and measured from combat records the effects of searcher speed, searcher altitude, and meteorological conditions on the probability that a submarine would be sighted. Physiologists contributed factors for the behavior of the eye, electronics engineers factors for the behavior of radar—to be worked into an overall theory of the search operation. The theory, in turn, provided the basis for best decisions as to allocation of searching effort, and as to which equipments were best.

Similar theories, or working models of the operations, provided tools for the best decisions regarding means for anti-submarine attack, for arranging convoys and their escorts, for bombing factories, for gunfire support of amphibious operations.

Operations research achieved stature in the Armed Forces when almost anything new was tried at least once in the desperate effort to defeat our enemies. Many new methods were called, but few were chosen. Operations research stayed, and has since become an important and accepted feature of our military organization, a tribute to its value and usefulness.

OR emerged from the war to find peacetime battles of production, sales, and distribution looking like familiar ground. Here, too, problems outside the conventional fields of science and engineering have yielded to the methods of scientific research. It has been found that many of the principles developed from military operations research could be transferred directly to the problems of business and industry.

WHAT IT IS

Many management decisions in industry require the selection of factors relevant to the outcome of an operation, determining values for each of these factors, estimating how each affects the outcome of the operation concerned, and, finally, selecting a course of action which will yield the most favorable outcome. Too often such decisions are based upon an incomplete understanding of the basic relationships among important factors, particularly when such relationships may be obscured by masses of unwieldy data. The result may be judgments based in too large a part on opinion, so that conflict and disagreement result.

Operations research tries to provide a more complete and integrated quantitative basis for such decisions, by defining explicitly the factors which should be measured; finding ways to isolate them from among complex data and to determine their values; and establishing explicit quantitative relationships among them which can be used to predict the effects of alternative decisions.

An operations research attack on a problem is basically that of the scientific method, an unbiased systematic approach. Many of the techniques used are not new, only their wider applications. Scientists do not know more about war than military men, or more about business than businessmen, but they do bring to their problems a new attitude, as well as new techniques, and formulate problems in a new language.

HOW IT WORKS

The operations research approach may commence with the selection of measures of effectiveness in terms of which the success or failure of an operation is to be judged. These may be quite different from those previously employed. As an example, during the war the Navy provided crews to man anti-aircraft machine-gun defenses for merchant vessels. It was noted that the proportion of attacking enemy aircraft shot down by such batteries was very small compared with AA experience of naval warships. It was suggested, therefore, that the naval gun crews could find better employment elsewhere and should be withdrawn from merchant vessel assignment. Closer study indicated, how-

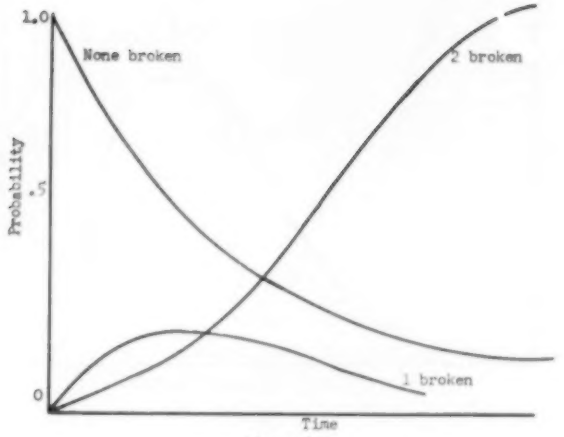

Figure 1

ever, that in the case of merchant vessels defended by machine-gun batteries, the ships hit per attacking aircraft were much lower than for undefended vessels. The correct measure of effectiveness to employ in this decision was ships hit per attacking aircraft, rather than aircraft shot down per attack.

A recent operations research study concerned with evaluating the effectiveness of a chain of retail outlets for a large manufacturing company found that different officers of the company were, perhaps unconsciously, applying widely differing measures of effectiveness in reaching conclusions as to the success of the retail chain. (In this, and following examples, we are forced to paraphrase or abbreviate statement of the problems, in order to protect the confidences of the companies involved.) The president felt that the chain should be operated in such a manner as to maximize profits to the company; the treasurer wanted to see them adjusted so as to maximize return on invested capital; the sales manager was interested in gross margin, or sales less expense. It was discovered that these varying measures of effectiveness were mutually incompatible, and that the store chain could not be operated to maximize them all at once. It was necessary to develop a new and different measure which represented in proper proportions the interests of the various officers of the company, and to which they could all agree.

The next step in the operations research approach may be the development of a working model of the operation studied. This model usually takes the form of a set of mathematical expressions, since words are unwieldy, and because mathematical equations provide means for manipulation, extrapolation, and maximizing. The model provides a theory of the operation, which can be used to predict quantitatively the effects of alternative courses of action. It is not an abstraction, and every part of it should have a physical and practical meaning.

In order to illustrate what we mean by a working model, let us look at a simple theoretical example of the development of a model of an operation. In a certain production machine is a bearing secured by two bolts, which are subject to breakage. If as many as one of these bolts is intact, the machine can be operated. If both break, however, the machine is down for twenty hours for repair and adjustment. An inspection of the machine while it is still in running order, to ascertain the condition of these bolts, and to replace one if broken, would require the machine to be down for two hours. The decision required is whether or not to institute a program of regular inspections of these bolts and, if so, the interval at which such inspection should be carried out.

The measure of effectiveness selected is the expected fraction of the time that the machine is out of service, which we wish to minimize. An examination of operating data showed that the average lifetime of a bolt is 1,000 operating hours, provided that both are intact and sharing the load. After one bolt is broken, the average lifetime of the remaining bolt was found to be 200 hours. Furthermore, an examination of the distribution of bolt lifetimes around the average showed that breaks appeared to occur at random, so that distribution of bolt lifetimes could be taken to be exponential.

From this information and probability theory, it is simple to produce a model of the operation in the form of probabilities that none, one, or two of the bolts would be broken after a machine had been operated for any given number of hours after an inspection. These probabilities would appear as shown in Fig. 1.

An extension of this model to include the times required for inspection or repair provides a relationship between the fraction of the time that a machine should be out of service and any given inspection interval, which takes the form of Fig. 2.

For those interested, the formula for this "decision function" is

$$f = \frac{20 - 30e^{-t/500} + 12e^{-t/200}}{720 - \frac{2590e^{-t/500}}{3} + \frac{438e^{-t/200}}{3}}$$

An expression like this, rather than something constructed from wood and steel, is the "working model" as seen by operations research. In this simple illustration the techniques needed to develop it were relatively simple. In practice, techniques beyond those normally used in engineering—such as communications theory, game theory, linear programming, or variational calculus—as well as probability and statistical theory, are often drawn upon.

Another step in the operations research approach is typically to check the working model against operating or experimental data reflecting varying conditions, in order to determine whether the model can be counted upon to reproduce actual results when such factors as time, place, or type of product are varied; adjusting the model if need be.

As a final step, the adjusted model is used to provide a useable basis for decision by solving it for the optimum levels at which the operation should be carried out, predicting the effects of alternatives, and devising

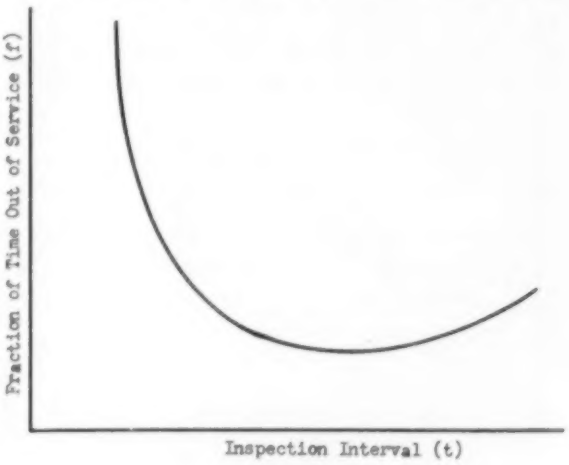

Figure 2

simple rules or control charts so that operating personnel can apply the rules for best operation.

EXAMPLE—EVALUATION OF A NEW DEVELOPMENT

In connection with the development of a new transportation control equipment, a company required a quantitative measure of the degree to which it would improve the operation. The technical characteristics, costs, and reliabilities of the proposed equipment and those which it might replace were pretty well known. There was no good way, however, to place it in an operation rather than a technical environment, and there to compare it quantitatively with competing equipments.

A principal contribution of OR to this problem was to develop a new measure to describe an elusive characteristic of railroad operations—the delay to trains caused by one train waiting for another at crossings or sidings—akin to a safety factor. Neither the developing company nor the operations research team were prepared to tell railroads what this time delay factor should be and practice varied widely. But, they could provide a measure for it, and show how it affected the control operation.

So a measure called a "passing parameter" was developed. This was merely

$$P_\theta = \frac{T_1 - T_2}{t}$$

where T_1 and T_2 were the times at which trains were scheduled to arrive at a possible point of conflict—such as a siding on a single track road—and t was the time it would take the faster or heavier train to decelerate and stop.

A working model for a typical actual stretch of road was also developed, in terms of the speeds, accelerations and densities of trains thereon during a typical operating day, and the number of meeting points involved. The measure of effectiveness chosen to compare alternative control systems was total train delay per day due to control. From these measures a quantitative picture of the relative operational suitability of alternative control systems could be presented in terms of a factor which remained under the control of the operating personnel.

EXAMPLE—PRODUCTION AND INVENTORY SCHEDULING

A problem frequently encountered in one form or another is how to schedule production and inventories to meet seasonal or severely fluctuating sales, at minimum overall cost. In a recent case, existing policy was to

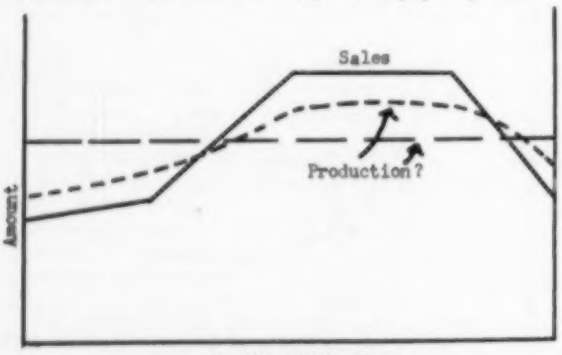

Figure 3

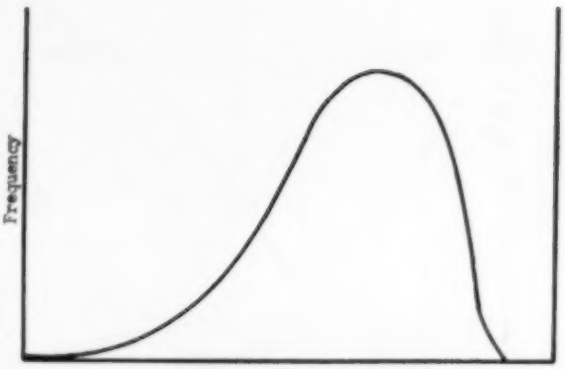

Figure 4

schedule production relatively uniformly throughout the year to meet the sales forecast with a minimum of overtime and alteration of labor force, letting inventories take up the slack.

Although this suited the production manager, the treasurer was unhappy and thought this practice involved unnecessary storage costs and tied up funds in too large inventories. The sales manager was satisfied as long as inventories were always large enough so he could meet demand without running into back orders and their attendant loss of good will, loss of customers, and artificial stockpiling. Scheduling had been difficult because of the large number of products and production lines, and several factors were involved which weren't measured and could only be argued about.

The working model of the operation used the total of costs associated with the schedule as a measure of effectiveness to be minimized, and summed separately the costs associated with production, inventorying, and back-orders—each group representing the interests of one of the interested executives. Severely summarized, it looked like this

$$\text{Cost} = \Sigma\, C_P(P_m) + \Sigma\, C_I(I_m) + \Sigma\, C_{BO}(I_m)$$

where

$C_P(P_m)$ = Cost of producing (in any month) an amount of production P_m

$C_I(I_m)$ = Cost of carrying in inventory an amount of inventory I_m

$C_{BO}(I_m)$ = Cost of back-orders associated with an amount of inventory I_m

Once the model was set up, the best schedule can be solved for by the technique of linear programming, an arithmetic for solving such an expression, subject to restrictions imposed by capacities to produce or store, and company policies such as those relating to permissible overtime.

Important features of the operations research problem, however, were the limiting of costs appearing in the working model to those related to the production schedule—*when* the goods were produced—and assigning values to some of them which weren't measured before. For instance, the cost of raw materials had to be borne sometime during the year, so was essentially unaffected by the production schedule. On the other hand, costs of overtime production had to include costs of setting up extra shifts and any increased costs due to less efficient labor and supervision. Back-order costs, except for those due to extra handling and bookkeeping, had not been measured before. Although it was difficult to cost loss of customers and good will, solving

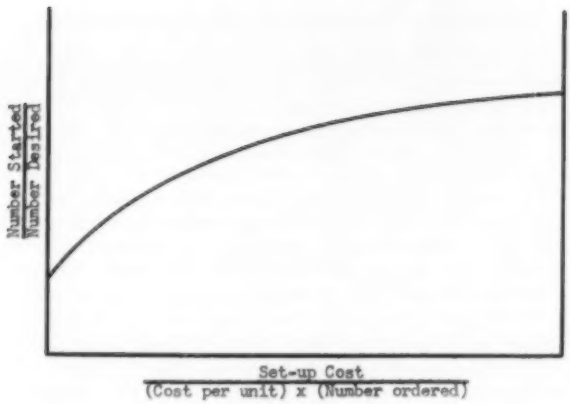

Figure 5

the model against previous production schedules revealed the values unconsciously assigned to back-orders in practice, bringing them out into the open for examination. Graphical methods were developed to show the effect of the choice of back-order costs on minimum inventory levels and carrying costs.

The sum of overtime and inventory costs for the optimum schedule turned out to be 44 percent of those for the schedule previously planned. A quick and simple method for extending optimum scheduling to all production divisions of the company was devised, as were methods for altering schedules with changes in costs. Guesswork in scheduling was eliminated and argument reduced to discussions concerning the values of component factors, with knowledge as to how variation in any of them should affect overall costs.

EXAMPLE—PLANNING MACHINE RUNS

A manufacturer of small components on a job basis was faced with the problem of estimating the number of pieces to produce on any one order, since the fraction of pieces discarded because of scrap or spoilage varied widely from run to run of the machines. Customers normally would accept up to a ten percent overrun, but if larger numbers of acceptable pieces were made, the excess could only be scrapped. If, on the other hand, spoilage resulted in the number of acceptable pieces being less than ordered, an expensive new machine set-up and rerun was required.

The operations research team, after examination of production data, found that the distribution of finished output as a fraction of started quantity could be expressed by the equation

$$\Phi(x) = k\, x^{a-1}(1-x)^{b-1}$$

where

- x = Fraction of started quantity which was acceptable
- $\Phi(x)$ = Relative frequency of runs producing an acceptable fraction x
- k, a, b = Constants, to be solved for.

The analysts found that this expression fitted data for all products, with the constants k, a, and b varying somewhat among items, and, when charted, appeared as shown in Fig. 4.

Since gross profit was the measure which the production manager wished to maximize, this was selected as the measure of effectiveness, and the following expression derived

$$P = P' - s\int_0^{A/S} \Phi(x)dx - cS\int_{1.1\,A/S}^{1} (x - 1.1A/S)\Phi(x)dx$$

where

- P = Gross profit
- P' = Gross profit if just the right number of units is made
- A = Number of finished pieces desired
- S = Number of pieces started
- s = Cost of an additional machine set-up
- c = Cost per unit produced.

The second term of this formula represents the average loss due to additional set-up, and the third term the average loss due to overrun.

Maximizing this expression for profit yielded a curve such as that of Fig. 5, from which to choose the optimum number of pieces for an initial run. This curve shows, of course, that the larger the machine set-up cost the more leeway for waste should be provided in the number of units started. The proper number of units started could be readily computed to provide the optimum balance among additional set-up cost, surplus scrap cost, and order size.

EXAMPLE—DETERMINATION OF PRODUCTION COST FACTORS

Estimation of unit product costs is of prime importance to industrial managers as a basis for controlling the efficiency of production operations, as part of the information needed for setting pricing and sales policies, and as a guide to direction of engineering effort. The two most common sources of unit costs appear to be time studies and engineering or technological requirements or limitations.

There are many cases when time standards are neither specified by the technology nor readily determinable by time-study methods. The operating times of complex semi-automatic multi-purpose equipment with fairly long production cycles may depend both on the efficiency of the operator and, in a complex way, on a number of characteristics of the input materials. The length of the individual production cycle, the wide variation in operator tasks depending on the particular job assigned, and the number of possible uses of the equipment, may make usual time-study or job-analysis methods unworkably cumbersome. In such cases, operations research analysis of routine statistical data from shop operations in the light of a realistic mathematical model reflecting the important machine and product characteristics may be used to derive usable time standards.

An example arose recently in a study of some operations in an electrical wire plant. The operation concerned was that of "horizontal taping," in which a partly completed cable is covered with a helical layer of cloth or metal tape. This is done by pulling the cable

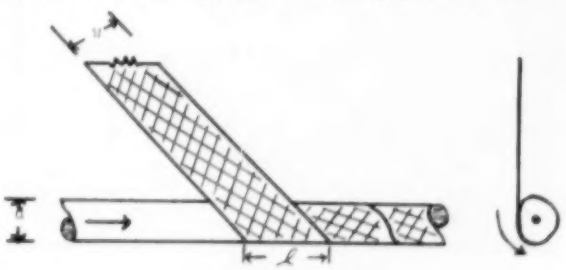

Figure 6

through the center of a rotating disk, the "taping head," which carries a roll of tape. The tape is unwound, and through a set of rollers presented to a moving cable at an angle such that in one rotation of the taping head one turn of the helix is placed upon the cable with a prescribed (small) overlap.

There are thus two inputs: first, the cable, which has two important characteristics—the diameter, and the state of cure of the rubber insulation; second, the tape, which also has two characteristics—width, and kind of tape. Only a single product was produced from a given set of input materials, so that there was no dependence of production rate on the product characteristics.

In setting up the model for this machine, some assumption had to be made concerning the nature of the property that limits the speed of taping. It was assumed that taping speed is limited by the tensile strength of the tape, which must be unwound from its roll at a high rate. A model was established from the geometrical characteristics as shown in Fig. 6.

On the assumptions that the tension in the tape is proportional to its speed, that the strength of the tape is proportional to its width, and neglecting overlap, the limiting machine speed is

$$K \frac{w}{\sqrt{\pi^2 d^2 + l^2}} = \frac{l\pi d}{\pi^2 d^2 + l^2}$$

and the time required to produce a length L of product is

$$T = t_0 + K \frac{L}{l}\left(\frac{\pi d}{l} + \frac{l}{\pi d}\right)$$

When attempts were made to fit this equation to available data (time and payroll information for several hundred jobs of varying length, cable diameter and lay) values of the constants for the three machine types involved were inconsistent, and, in some cases, physically meaningless. However, by recognizing correlation among variables and bias caused by the prevalence of short jobs, modifying least-squares procedure by trying geometric means and combinations of variables, satisfactory constants were found. The model then explained 94 percent of the original variance with physically meaningful constants, and revealed the fundamental differences among machines and products.

It was possible to set up a job "quality control chart," based on estimates of the standard deviations of the values of t_0 and K. There is considerable uncertainty in the time required for identical jobs, but with the aid of this chart, the foreman is able to decide if the time required is unreasonable or not.

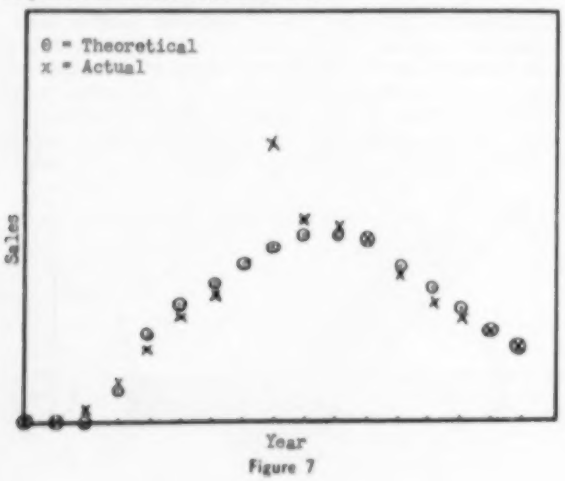

Figure 7

EXAMPLE—EVALUATION OF ADVERTISING

As a final example, a company sells a large number of products, all of which are normally promoted by direct mail and magazine advertising. Their advertising executive has a difficult problem in deciding how much of his department's available effort should be budgeted to each product.

In setting up such budgets he must take into account such factors as the total market potential of each product, differences between products, appeal to the consumers, and the rate at which sales will drop off if he stops advertising. He, of course, considers a great many other factors such as differences between media, and the extent to which competition is advertising its products.

In order to help him, an operations research group set about to see how much of the variations in the sales history of products could be explained by a model which takes into account the advertising effort devoted to each and three of the principal relevant factors: sales potential, a measure of the market response to advertising, and the rate at which sales would die off in absence of advertising. Other factors were assumed to average out over all products and were neglected in initial analysis.

The sales potential represented the amount of the product which the market could absorb with an infinite amount of advertising, the saturation level. The market response was expressed in terms of the dollars of annual sales to a customer newly attracted by each dollar of a moderate amount of advertising. The "death rate" was assumed to be a constant percentage applied to each year's sales.

These three factors were combined in a differential equation expressing sales for any year in terms of the advertising history up to that time. Solved for values of the three factors provided excellent agreement between actual and theoretically expected sales in several cases, of which an example is shown in Fig. 7.

Sales rose rapidly during the early life of the product when advertising expenditures were made at a fairly high rate. At one point it was decided that the product was beginning to go out of style and advertising expenditures were cut back in order to provide money to support more stylish products, and sales dropped. Finally, advertising was stopped altogether and sales fell off at practically a constant percentage rate per year, much like a death rate in a population. The marked difference between actual and expected sales for one year was traced to a type of sales where no influence of advertising was possible.

The fact that practically all of the variations in sales over the life of the product were explained in terms of three factors made it possible to set up procedures for helping the advertising executive budget his available effort after estimating the values of a few of the relevant factors.

These examples represent only simple illustrations of the scope of operations research. It has been useful in other areas such as the evaluation and control of sales promotion programs, the design of optimum distribution systems, and financial planning requiring the evaluation of alternative demands for capital expenditures. The ultimate goal of a company's operations research team—a very distant goal in most cases—is to provide a quantitative model of the operations of the entire enterprise. The framework upon which such a model would be built—and within which the important relationships would be established—may look much like what is often called the duPont Investment formula,* illustrated

*How the duPont Organization Appraises Its Performance. AMA Financial Management Series No. 94.

by Fig. 8. Here, return on investment has been chosen as the ultimate measure of effectiveness, and the effects of a change in any of the important operating areas of the company can be traced to it.

WHAT *OR* ADDS

The question has often been raised as to how the work we have here called operations research differs from some of that which is done within the engineering or research departments of progressive companies, or by management and systems engineers.

At Arthur D. Little, Inc. we have long been engaged in various aspects of development and engineering—particularly those with a technical touch—such as diversification or plant location studies, process flow and materials balance studies, and problems associated with acquisition and merger. And we have compared operations research with these activities in order to try to distill some factors of difference.

One key may lie in the definition of research recently cited by Mr. Mitchell, President of Sylvania—that research is the seeking for knowledge you do not know exists when you start rather than the application of known engineering principles. It can be distinguished by the kind of people doing it—a research team with a variety of scientific backgrounds. It can be distinguished by the analytical methods required, which are usually non-standard, sometimes rather advanced, and may be drawn from any one of a variety of research fields. A member of a prominent firm of management engineers, in comparing OR and management engineering in a recent article, suggests that OR techniques take up where those of industrial engineering leave off.

The emphasis of operations research on the quantitative leads some people to identify it with statistical or accounting analysis. Actual examples indicate, however, that its fundamental objective and contribution is to reveal the basic relationships underlying the operations studied. As in physics and chemistry, theories of underlying mechanisms are sought which are consistent with facts brought out during operations or experimentation, and which can be used to predict the effects of changes in procedure or environment. Like statistics, operations research uses probability theory as a basic tool, but it seems to be ready to employ techniques from many fields, or some which may be specially developed to achieve its objective.

We find, therefore, that successful OR solutions of industrial problems usually result in one or more of the following

1. New measures of effectiveness
2. New ways to interpret data
3. New ways to measure factors not measured before

where "new" means that they were different from those previously applied to that type of problem.

DEVELOPMENTS IN OPERATIONS RESEARCH

The recent formation of the Operations Research Society of America by representatives from industry, government, and universities; the appearance in October, 1952 of the first issue of a journal for the Society; and the first national meeting in November, mark further steps in the growing interest in the application of the methods of scientific research to operating problems of management. The November meeting of the ORSA provided an interesting indication of the scope of present OR techniques and applications. Examples of operations research in production and inventory scheduling, evaluation of costs in machine operations, aircraft maintenance, seaport operations, maketing and agriculture were presented.

Several companies have consciously established operations research groups, some with origin and emphasis in production areas, while others concentrate on marketing problems. Much work similar to operations research has been done under other names. In some companies, development of new products and processes is accompanied by major research effort to measure the impact on sales or operating costs. One organization reported the formation of groups composed of representatives from research, production, and sales divisions to study manufacturing operations and recommend improvements. In the petroleum industry, some research departments have analyzed exploration and production data to provide scientific bases for operating petroleum fields for maximum yield, and for adjusting refinery operations to the best product mix in the light of current price structures and market demands. In some cases, research teams have been asked to provide improved quantitative bases for choosing the best locations for service stations, or for new plants.

The extent to which study by scientists of management problems which arise outside of the research laboratory will expand and be recognized as operations research is not yet clear, but a pattern seems to be emerging. Those organizations which have a long history of substantial research effort well integrated into the management structure—often evidenced by the creation of subsidiary research corporations—tend to apply first-class scientific study to operating problems up to high management levels. A rough relationship may exist between the degree to which a company's products are research-based and the depth of penetration of research methods into the management operations of the company. The natural growth of research within a company leads to its emergence from the laboratory to deal first with problems of how new products or processes affect sales and costs, then to manufacturing processes and productivity. It is then applied to scheduling of production and inventories, to physical distribution, and later to the evaluation of sales, advertising, and promotional efforts.

When scientific research personnel, using the theoretical and quantitative methods of the basic research, have participated in creating the bases for decisions in all of these management areas for any company, there exists operations research in its most effective form, regardless of what it may be called.

RELATIONSHIP OF FACTORS AFFECTING RETURN ON INVESTMENT

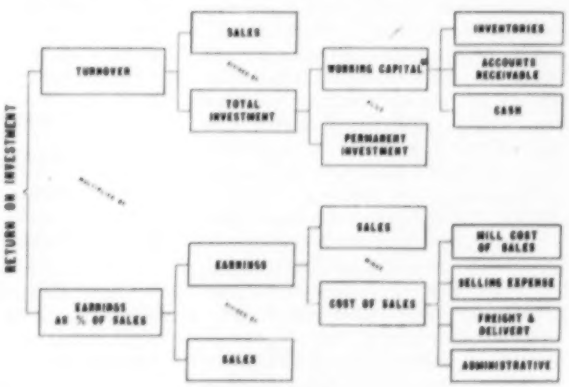

Figure 8

OR Concepts Useful in QC

HAROLD O. DAVIDSON

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INTRODUCTION

The title of this article might be regarded either as a statement which is asserted to be true, or as a proposition which may or may not be true. I prefer to regard it as a proposition which may or may not be true depending upon what you mean by "Quality Control" and what I mean by "Operations Research." In an article of this sort there is some advantage in starting at a point where nearly everyone can be in agreement. To this end I think it can be stated that Quality Control and Operations Research are broadly similar activities in these respects

(1) They are directed to (materially) *useful objectives*
(2) They deal with *types of problems*, which can be *analytically generalized*, in working toward the objectives
(3) They have developed or adapted *objective techniques* for solving these problems.

This is perhaps an overly simple way to characterize a general class of activities of which both Operations Research and Quality Control are members. However, this scheme does serve to indicate the relative order of importance and consideration; objectives, problems, techniques. Without a clear definition of the objectives one cannot intelligently formulate a problem, and without a formulation of the problem it is rather useless to grope around for techniques.

TECHNIQUE ORIENTATION

I would like to emphasize as forcibly as possible this order of consideration—objectives, problems, techniques. As I will show later it is the order which Dr. Walter A. Shewhart followed in his pioneering quality control investigations. There is a strong tendency, however, for many persons both within and without a given profession to define the particular field in terms of its techniques. This historical approach does have a certain pragmatic appeal, for by stating rather specifically what the capability of a profession has been in the immediate past it indicates approximately what it can do in the immediate future. There is also a pronounced tendency to concentrate effort on further exploitation of techniques which have proven successful while neglecting the problems for which adequate techniques have not yet been developed. The complacent indulgence of this tendency is a sort of professional malady which I would call technique-orientation. A strongly technique-oriented profession will continue to improve its traditional methods of solving problems but is relatively sterile insofar as the innovation of new techniques is concerned. The mere improvement of traditional techniques, however, will rarely avail to keep a profession abreast of the dynamic industrial society in which the important problems of one generation are not necessarily the important problems of the next. The technique-oriented profession, then, may show a continued improvement of techniques, for the solution of decreasingly important problems — because it has lost sight of the original objectives upon which the profession was founded or because the original objectives are no longer the proper ones.

Every profession is susceptible to this disease and suffers from it to a greater or lesser degree. It has been very apparent in the time study area of Industrial Engineering. It has appeared in Quality Control. And I have observed signs of it in as new a profession as Operations Research. In speaking of technique-orientation as a disease I intend a quite literal analogy. It is definitely contagious, being transmittable not only by persons who are infected with it but also by technical journals. It saps the vitality of a profession; and it impairs the profession's usefulness to society by virtue of an accompanying disability—to which Operations Research people have applied the term "sub-optimization."

SUB-OPTIMIZATION

Sub-optimization results whenever a problem, or part of a problem, is defined without adequate reference to its context; so that when an apparently best solution is found, it is not in reality the optimum solution with respect to the over-all problem. In many cases this amounts to solving the wrong problem, or to the solving of trivial problems. The sub-optimization fallacy obviously is not something that was just discovered by Operations Research. I am quite sure that it has been noted by people in every profession. At the same time, the general reaction in most technical professions is to conclude that this is a matter for somebody else to worry about; "it's outside *our* field."

The inadequacy of this viewpoint lies in the fact that problems in the real world are not broken down into neatly separable packages labeled Sales Problems, Quality Control Problems, Production Problems, Labor Problems, and so forth. These divisions are something that we impose rather arbitrarily, though with the admittedly sensible idea of reducing the general problems to manageable bits that people can work on. Troubles begin when each person runs off into his own departmental hole to work on his bit of the problem. And the troubles converge to torment the executive when the sales department informs him that the product must have longer life, better appearance, greater efficiency, and lower cost than the competitors' products. The production department insists that quality standards must be lowered in order to meet desired production schedules. Design engineering claims that the standards must be raised in order to achieve the specified wearing qualities of the product. Industrial Relations complains that excessive rejects are causing employee dissatisfaction with the wage incentive system. Meanwhile, the quality control director has been squeezed by the same pressures so that he, at least, may offer the managing executive something which the others probably do not; namely, sympathy. The technical work of quality control, however, is all too often as much a sub-optimization as any of the rest. I will offer illustrations in support of this point later in the article. At this point I would like to make sure that I have presented a reasonable view of the sub-optimization problem.

THE CONCEPT OF STRUCTURE

In speaking of persons working independently in their own depart-

(Continued on page 12)

QC Concepts Useful in OR

PAUL S. OLMSTEAD
Bell Telephone Laboratories, Inc.

INTRODUCTION

Since World War II, Operations Research has received extensive publicity as "a scientific method of providing executive departments (and, therefore, executives) with a quantitative basis for decisions regarding the operations under their control."[1] This has excited the interest of many scientists and some of the more erudite executives. As a result, short courses similar in some respects to the eight-day courses in Statistical Quality Control, have been given at several universities. More recently, a few universities have organized Operations Research curricula. This development has been in the direction of establishing Operations Research as a new science.

However, others, particularly engineers, have been inclined to consider OR primarily as the application of recently developed mathematical techniques to the analysis of complex situations. As such, it is a part of Industrial Engineering, Systems Engineering, and, of course, Quality Control. The fact that it may be a part of each of these and many others suggests that people from these several fields may wish to get together to discuss their diverse problems. This should obviously lead to more wide-spread use of specific techniques that might otherwise be developed for use in only one field. A simple example is the extension and application of QC techniques to clerical work, to merchandising, and to many other fields.

It is just as important for QC people to find out more about OR as it is to find out about the latest development with the particular product for which they are responsible for quality. At the same time, it is important for QC people to inform OR people about fundamental theory of QC that should be useful in applying OR to other fields. That is the primary objective of this article.

An OR problem that each QC person has encountered is the determination of an assignable cause. Ordinarily, this would be taken to be simply QC. However, it is a problem that might be assigned to an OR man to solve. But will his method of solution be different?

BASIC *OR* PROCESS APPLIED TO A SPECIFIC PROBLEM

If a person is assigned to solve a particular problem, he must first be told about the problem, i.e., what is wanted. This is not always easy. Sometimes the want is contingent on what is found during an investigation. For purposes of simplicity, it may be assumed that the problem here can be reduced to finding the cause of some undesired effect that has been observed in a process. This may be formalized as

Statement of Problem—To find the assignable cause associated with the undesired effect observed in the process.

The obvious next step is to take a look at the process. This may involve reviewing the theory relating to the operation, the troubles that had been encountered previously, and the data that are currently being obtained. In some cases, it may even be necessary to obtain new data. At this point, it may be worth while to mention something about how this is done in OR. Where ordinary scientific method might assume this to be a one-man job, OR recognizes that most operations are complex and may require consultation with a number of people. Usually, the assignment for solving a problem is given to a team rather than to an individual. The leader of such a team then acts primarily as a coordinator. Formal designation of this step might be

Collection of Information for analysis from all available pertinent sources, including

1. Accepted *Theory* for normal operation from scientists or designers,
2. Possible *Hypotheses* about troubles from scientists or engineers, and
3. *Data*, both existing and new, from QC or other records.

The emphasis in the OR approach is on people and the ideas that people have. It is recognized that the same set of data mean different things to different people. For this reason, a group approach to a problem is apt to give a better answer than that obtained by one man working alone.

In trying to find the assignable cause associated with an undesired effect observed in a process, it is likely that the OR man would first determine the intent of the process and the background of its development from the engineer who designed it. This is to provide a picture of accepted theory relating to the process. It also may disclose information relating to troubles encountered during development, together with their effect on the output of the process. This may suggest possible hypotheses about the assignable cause being sought. The next step is to see what is actually happening in the process. On the basis of accepted theory and the possible hypotheses, existing data are examined, the process reviewed with the engineer in charge, and in some cases new data obtained in order to secure a more complete record of associated happenings. Sometimes, the process review suggests new possible hypotheses which require additional new data. The extent to which the search for information would be continued depends on the experience of the OR man and his judgment about the sufficiency of the theory, hypotheses, and data for the next step in solving his problem. This step is a *Critical Analysis of Information*

In many respects, this step in an OR investigation is applied statistics. In the statement of the problem, it was assumed that originally the process was free from the assignable cause now believed to be present. This can be tested by showing that before the present situation developed the process was in control. Control chart presentation of past data, therefore, should show that control had been attained and thus confirm the reasonableness of accepted theory. Continuing the control charts to recent data should show that at least part of the data is outside control limits. This would confirm the assumption on which the investigation was started, namely, that an assignable cause is present. To find out what the cause may be requires other information.

A starting point is to consider each of the hypotheses and the new or old data that relate to them. In some cases, Design of Experiment may have provided data suitable for an Analysis of Variance that is carried out. In others, particularly where

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mental holes I am speaking figuratively with respect to professional methodologies. I do not mean to imply that no communications exist between persons, or that there is a total lack of mutual interest in achieving a genuine optimization of the general problems of the enterprise. Communications, both informally and by committees, do exist between departments. And not infrequently there is a substantial realization of the necessity for optimizing the solutions to problems on a higher-level than has been accomplished in the past. From my own observation I would say that this attitude is somewhat more common in progressive quality control organizations than in most other technical departments. In enterprises that are not too large competent people working under these conditions are often able to achieve a very good degree of optimization for the general problems of the company. But as the size of the company increases the communications between departments tends to be less effective, and the complexity of the problems increases so that the determination of optimum solutions becomes virtually impossible without the aid of a specialized approach and methodology. The idea expressed here is no more radical than the notion that a civil engineer can design building structures more efficiently by means of his specialized approach and techniques than can a construction foreman by means of rough "principles" and guide rules. The Operations Research viewpoint holds that organizations and their operations are also "structured" and that it is possible by scientific investigation to discover useful knowledge about them. This provides the basis for an approach and methodology for efficiently determining optimum solutions for the organizational-operational problems. In brief, this is the central concept of Operations Research.

I am quite aware that many persons take a rather pessimistic view of the possibility of applying analytic methods to resolve diverse elements of large-scale problems and produce optimum system designs and operational procedures. Anyone who has engaged in the sort of Operations Research I am talking about would certainly agree that the task is a forbidding one and that the methods available today are by no means everything that we would like them to be. Even so the accomplishments of the Operations Research profession during its first ten years are ample evidence for belief that its central concept is sound. This is not always clear to an observer who is puzzled to find that some work labeled Operations Research could in all probability have been done just as well by one of the other professions. The only remark which can be made to this point is that there have in fact been a dismaying number of instances where the Operations Research label has been indiscriminately or mistakenly applied. No doubt some of these are the result of genuine confusion; for by a technique-oriented inspection Operations Research looks like applied statistics from one aspect, like Industrial Engineering from another, and like Applied Physics from still another. And this is not surprising, since the founding of Operations Research as a profession essentially represents the gathering together from many different professions of persons who for some time had been working toward the same central concept. The amalgamation of techniques from many different sources was a quite natural result. This in itself has had obvious advantages. Perhaps an even greater advantage accruing to a coalition of professional backgrounds is the fact that it develops an improved facility for bringing the apparently diverse aspects of a problem into a consistent perspective. In other words, it supplies something which our compartmented and specialized system of education generally fails to develop.

THE QUALITY CONTROL VIEWPOINT

What I have attempted so far is not a comprehensive definition of Operations Research but rather an exposition of the Operations Research viewpoint. I have indicated that it is a viewpoint which was developed simultaneously by people in many professions, and I am sure that it is to be found today in the advance elements of every profession. Nevertheless the great bulk of Quality Control practice today is an extension of the work of Dr. Walter A. Shewhart and is based to a great extent on the objectives, problems, and techniques as he defined them.

> ". . . we shall start with the aim of the engineer to manufacture a product of uniform quality. We shall take this to imply that the quality should be reproducible within limits, or that the engineer should be able to predict with minimum error, the percentage of the future product that will be turned out by a given process with a quality within specified limits. The engineer desires to reduce the variability in quality to an economic minimum. In other words, he wants
>
> (a) a rational method of prediction that is subject to minimum error, and
>
> (b) a means of minimizing the variability in the quality of a given product at a given cost of production."*

This is the general point of view from which began the development of a considerable array of useful techniques applicable to problems of process control and acceptance sampling (and, incidentally, to problems of similar analytic form in many other fields.) There is no need to ask whether this has been worthwhile. The important question now is of the future development of Quality Control. Which direction should it go? Should there be a change of emphasis to other aspects of the quality problem?

Whether Operations Research can make any substantial contribution to this inquiry is something for the Quality Control profession to decide. I can say, however, that quality problems arise in every OR investigation and that there is a general method of approaching such problems, from the Operations Research viewpoint, which may be of interest to Quality Control people. As I have mentioned previously, the objective of Operations Research is the solving of problems in a way which will be optimum for the enterprise as a whole. This means that the goals of the enterprise must be clearly identified as a context for the problems considered. Without this step it is impossible in military operations, for example, to determine whether the purpose of a withdrawal action should be delay of the enemy (as in the Bataan campaign) or conservation of one's own force (as in the Dunkirk evacuation.) I might mention in passing that those who have the time and interest will find a dramatic illustration of conflict between sub-optimization goals in historical accounts of the Dunkirk operation in World War II. This case is particularly interesting since continued insistence on a sub-optimization goal might well have been fatal for the enterprise as a whole. Briefly, the withdrawal was conducted with the major objective

*Shewhart, W. A., *Statistical Method From the Viewpoint of Quality Control*. The Graduate School, Department of Agriculture, Washington, 1939.

of conserving British forces. Sub-optimization of the Dunkirk operation clearly indicated a necessity of local air superiority. On the other hand, conservation of British defensive air power required denial of air cover for the operation. The decision to discontinue air cover was undoubtedly a painful one, but the narrowness of the margin by which the subsequent Battle of Britain was won indicates how close to disaster the British nation had been pushed by temporary sub-optimization of the Dunkirk operation.

While commercial enterprise does not offer such clear-cut or dramatic illustrations of the principle, it is unquestionably important to know from the outset whether the organization goal is, for example, short-run maximization of profits or long-run stabilization of profits and jobs. This has an obvious bearing on the quality problem, and is suggestive of the importance which should be attached to identification of the organization goals as a prerequisite to definition of specific operating problems. From the operations research viewpoint the identification of organization goals is essential to the formation of valid "pay-off" functions.

CONCEPTS OF EFFECTIVENESS AND QUALITY

The next step in an Operations Research approach is formulation of the problem. There are various ways of going about this but one which is often productive is to ask where the problem actually originates, and then by tracing its effects to determine the "system" with which we must be concerned in order to solve the problem. Studying the quality problem system is a sort of loop which begins and ends with the consumer. This conclusion is forced upon us I think by the fact that the ultimate disposition of commercial goods and services is in the fulfillment of some consumer need. In a fundamental and important sense the "product" of the entire loop process is the *effect* produced for the consumer (i.e., satisfaction of his requirements.) Considered in this light the concept of quality is related to the Operations Research concept of effectiveness. Effectiveness is simply the extent to which a particular article or service satisfies the consumer's requirements. By fixing a certain set of requirements as a reference point we can assign fixed values of effectiveness to alternative articles or services and thus determine what we call quality. Effectiveness is therefore a somewhat more general concept than quality. For purposes of this article, however, the similarities are more important than the difference. Whether we use the concept of quality or the concept of effectiveness we are faced with the fact that there is no practical method or scale for directly measuring the degree of satisfaction of consumer requirements. In both Quality Control and Operations Research, therefore, we are forced to employ approximate measures of quality or effectiveness. In other words, since quality or effectiveness cannot be measured directly we are reduced to estimating it by means of criteria.

This problem can be illustrated quite simply by considering the quality of a Diesel engine, a common commercial article of manufacture which is capable of satisfying certain consumer requirements for power. An important quality characteristic of this article is its service life. It is unlikely, however, that the manufacturer will apply quality control techniques to service life. Instead, they are applied to such properties as dimensional variation, surface finish, and hardness of certain parts of the engine. This is done because there is reason to believe that these properties are functionally related to the quality characteristic which is really important to the consumer. The fact remains, however, that the control activities are directed to the criteria and not to the fundamental quality characteristic.

CRITERION BIAS AND SCALE DISTORTION

Criterion bias is one of the frequent and often unrecognized sources of sub-optimization, both in Quality Control and in Operations Research. One of the most interesting forms of criterion bias is scale distortion. A simple illustration of scale-distortion bias comes to mind in connection with the manufacture of booby-trap firing devices during World War II. Considerable quality control effort was expended with the objective of securing high firing reliability of the devices. This naturally had adverse effects on the cost and on the production rate. A quick analysis suggested that if quality standards were reduced there would be an increase in production and lowering of costs which would more than offset the losses due to the transportation of duds and the military effort expended in employing them. But this also was a distinctly sub-optimal solution, and resulted from a failure to get to the base of the quality problem. It had been assumed that the function of booby-traps was to produce enemy casualties and the military effectiveness (or quality) of a dud was therefore zero. Consequently, the military effort expended in using a dud was erroneously considered a cost, in spite of the known fact that dummy booby traps were frequently employed. This latter observation was a clue to the fact that the primary military effect of booby traps is not the production of casualties but delay of an enemy advance produced by the necessity of locating and destroying booby traps which *might* inflict casualties. It became clear that from the standpoint of military effect the quality of the firing devices increased in some non-linear fashion, as the reliability increased up to a certain point beyond which there was virtually no gain in quality from an increase in reliability.

Another clear case of scale distortion arises in connection with the determination of quality of an infantryman's rifle. Insofar as the consumer is concerned the major product is enemy casualties, when the weapon is employed in defensive fire . The quality of a rifle in this type of action is its ability to produce casualties. Obviously, one of the important quality characteristics is accuracy of fire—not accuracy of the *rifle*, but accuracy of *fire*. This amounts to stating the self-evident fact that the military effect is produced by a man-rifle system, not by a rifle alone. It is apparent, then, that as the dispersion contributed by the rifle becomes appreciably smaller than that contributed by the rifleman its effect on the quality of the result becomes negligible. Hence the accuracy of a rifle, measured on the test range, is a scale-distorted criterion of quality.

THE CONCEPT OF ASSIGNABLE CAUSES

I have chosen the preceding illustration because it brings in another matter of interest. The discussion of this problem appeals for an orientation toward end-results (products) of man-machine systems in operation. I think that there is implicit in this viewpoint a concept of "assignable causes" which is extremely useful. If we were to apply the

quality control concept of assignable causes to the performance of the man-rifle combination we should probably study the dispersion of the individual shots with a view to detecting the effects of possible non-random causes. This might in fact be an interesting application of process control techniques, though I suspect that an experienced coach can detect most of the important non-random factors without this sort of assistance. Suppose now that we have a skilled rifleman and that the process is in a fairly good state of control from the Quality Control viewpoint. From the Operations Research viewpoint we will still infer the presence of "assignable causes" in the sense that the supposedly "homogenous" dispersion is in fact the joint effect of two independently acting cause systems. And from the Operations Research viewpoint the factoring out of the total effect the contributions assignable to elements of the system, whether independent or interacting, is essential to the determination of optimum solutions in the over-all sense.

I appreciate the fact that Dr. Shewhart's work was based on the tenet that one accepts the existing process and that in relation to this tenet the alternative interpretation of "assignable causes" is not particularly meaningful. It is also quite apparent that a great deal of useful work can be accomplished within the boundaries of this tenet, though at times it may be able to produce nothing better than a low order of sub-optimization by virtue of the fact that the solution to the quality problem is defective in some other part of the system. Perhaps what I am doing is inviting the Quality Control profession to take a bigger bite of the quality problem. Judging by past accomplishments I would guess that the results of such action would be beneficial to industry.

CONCLUSION

This article has been suggestive rather than exhaustive of the community of interest, actual and potential, which exists between the fields of Quality Control and Operations Research. In addition to the analytical concepts which may have usefulness in both fields there are problems of determining costs—such as the cost of defective product—which are troublesome to both. These problems I have not touched upon at all for want of space. Finally, because of the need for diverse professional backgrounds in an Operations Research group and because of the particular contributions which the professional Quality Control engineer can make I predict that the community of interest between the two fields will be cemented by the addition of increasing numbers of Quality Control engineers to Operations Research teams.

(Continued from page 11)

QC charts have been in use, results of investigations of out-of-limit performance may be available. In general, these would be expected to show that change in practice had occurred at the time of the poor performance. Any one of several possible ways might be used to identify the assignable cause sought.

Having located the assignable cause through such critical Analysis of Information, consideration is given to preparing a

Predictive Statement that summarizes

1. Limitations of existing *theory*,
2. Necessary new *hypotheses*, and
3. What new *data* may be expected to show.

In the problem relating to the found assignable cause, this Predictive Statement might take the following form:

A. After taking steps to eliminate the found assignable cause, it will be possible to attain control of the process consistent with existing *theory*, but

B. On the *hypothesis* that the found assignable cause will continue to affect the process, control of the process consistent with existing *theory* cannot be attained without process modification.

In some cases, a more specific statement relating to the expected average and standard deviation of the quality characteristic involved is possible. Many OR analyses set forth the cost factors relating to various alternatives such as A and B but this need not be considered basic to the OR method.

QC COMMENTS ON THE BASIC *OR* PROCESS

Many QC people may feel that the basic process outlined differs but little from what would be the corresponding basic QC process. However, this apparent similarity has been enhanced by citing an example from the field of QC. Most OR problems do not have QC backgrounds as OR people might view them. The usual QC approach is to assume that each problem is one of a set whose desired end result is a state of statistical quality control. The problem changes slightly with each repetition but inevitably leads to what is acceptable as an economic solution. From the viewpoint of QC, each of the four steps in the basic process is apt to be a cause of trouble or assignable cause. Experience in solving other QC problems has indicated the nature of some of these.

It is generally recognized that the Statement of a Problem is often incomplete. Modifications may have to be made to take account of costs, differences in what individuals or groups of individuals want, changes in what they want, and even the availability and the properties of materials. Even in the simple problem of finding the assignable cause, there are the implied problems of what can be done about it and what level of quality is to be expected if the answer is nothing. This omission from a complete statement of the problem might not become apparent until an attempt is made to make a prediction.

It is one of the fundamental assumptions of QC that information is never complete and that such information as is available may be misleading. One possible reason is that the individual or individuals responsible for collecting it may overlook important evidence; another, that accepted theory is sometimes false. This may lead to omitting the right hypothesis as one of those to be investigated. Then, too, some data are unsatisfactory as evidence. Another of the fundamental assumptions of QC is that effects of undetected assignable causes are usually present in every set of data. If these assignable causes cannot be detected by applying QC procedures, the data are unsatisfactory.

When the Information is not complete, it is almost certain that the Analysis will be unsatisfactory even if it makes maximum use of the available information. However, even when the information is complete, the analysis may still be unsatisfactory. This will be true if no attempt is made to detect and find assignable causes of variation. Often this occurs because the analyst assumes that the data constitutes a random sample

without making a statistical test to see whether or not this may be true. Determination of expected variability on the basis of accepted theory for comparison with actual QC performance is sometimes omitted. Again, actual performance may be accepted erroneously as the limit attainable in the process.

Each of the foregoing contributes to the validity of the prediction that can be made. To be good, a prediction must be based on a good statement of the problem, good information, and good analysis. A prediction is apt to be poor if accepted theory is inadequate or incomplete, or if accepted theory is insufficient for the practical problem. A complete prediction must not only show what must be controlled but also what will happen when control of each important component is not attained. Some predictions are good insofar as they indicate the expected average of a process but poor in indicating what may be expected for individual values. This can be avoided by using the QC concept of tolerance range. Predictions relating to tolerance ranges for individual values and for averages have been demonstrated in QC as most informative and useful for setting up schemes for continuing good performance in a process.

In these comments on the basic OR process, reference has been made to various QC assumptions that have been verified as being true in almost if not all applications of QC methods. These assumptions relate to experience with manufacturing a product. Conceptually, however, they would appear to apply with equal validity to any repetitive process. The next section discusses some of these concepts that can be applied to the OR process.

QC CONCEPTS WORTH APPLYING TO THE *OR* PROCESS

From the viewpoint of QC, all processes are repetitive in nature. This is particularly apparent in all stages of mass production. It may seem less apparent in other fields of application. However, if it were not for the repetitive nature of signing a check, people might have more difficulty than they do about having them cashed. The authenticity of a painting as judged by an expert depends on many items of a repetitive nature. It is not unreasonable, therefore, to expect to find elements that stay constant or change gradually in everything even in processes of thought. On this basis, the QC approach to the OR process assumes the concept that

The entire OR Process is one cycle of a Repetitive Operation

In setting down the steps of the OR process, no provision was made for such a repetitive operation. However, in discussing the steps, it became quite apparent that when something new was learned by taking the step, it often suggested that something should be changed in a preceding step. This is indicative of the cyclical nature of the process. The steps cannot be considered to be independent.

Viewed in this way, each so-called new problem becomes simply an up-to-date statement of an old problem. Solution of any problem is simply an economic stopping point. With tomorrow's data, the available information will be changed and the solution may be different. Today's answer, to be complete, must account for each of tomorrow's possible conditions as they are anticipated today. Often, today's answer is like yesterday's except for normal sampling variation or some small cumulative deviation that may turn out to be a trend. When today's answer differs in an important way from yesterday's, it is time to look for an assignable cause. This may have been introduced by a new statement of the problem, by introducing new information, by using a new method of analysis, or by expressing the prediction in a new way. The OR approach that emphasizes group examination of problems is very apt to turn up something new so that today's answer will be different from yesterday's. However, the OR answer to be acceptable must tie together yesterday's answer with tomorrow's possible answer as part of a QC type repetitive operation.

Accepting this concept of repetitiveness, it is a simple extension to accept the concept that the OR process is one cycle of a repetitive operation. Then, if the entire process is repetitive, each element in it is also repetitive. Of course, this means that change in any important element is apt to result in a change of each of the other elements. This is known to occur in many, if not all, QC situations and may be presumed for each OR situation. The desired end result of QC considerations is a state of statistical control. It is reasonable that this should also be the end result desired in an OR investigation because predictions based on such a state will have maximum validity. One of the important problems of QC is the establishment of a process for reaching such a state. For mass production, the major features of this process are well known. The process is less well defined for determining QC with respect to consumer wants, research and development, design and specification, and field performance. To the extent to which QC and OR overlap in these applications, it will be worth while to consider those QC concepts that have a bearing on the steps of the OR process.

QC Concepts Related to Statement of the Problem

It has been pointed out that the statement of the problem is seldom complete. It is the prospective consumer of the results of the process who phrases the original statement. It is his statement of what he believes he wants. It is based on the results of previous allied problems and is subject to modification when the initial results of this investigation become available. QC theory suggests that an adequate statement of the problem will be impossible until the final results of the problem are known and have been taken into account. This is the equivalent of reaching a *state of statistical control*, a specific concept of QC.

In some cases, the statement of the problem does not take into account the ultimate use that the prospective consumer has in mind. If there are several prospective users, each with his own application, an all inclusive statement of the problem may not even be possible. In this situation, one choice is to reduce the problem to an average that may be sufficiently close to satisfy most of the users. However, to the extent that the wants of the users can be divided into subgroups, it is sometimes possible to make separate solutions for each. In QC, this is division into homogeneous subgroups or by assignable causes, another specific concept of QC.

QC Concepts related to Collection of Information

The interrelationship among theory, hypotheses, and data has been considered at some length in QC literature.[2,3] It is recognized in QC that not all data are good. Some may come from a process that is in a state of statistical control but others may not. In most cases, experience has shown that they do not. For this reason, QC has introduced the concept of an assignable cause and insists that all data should include sufficient information to permit detection and identification of such a cause. On this basis, all good data should include

1. The *Order*, i, associated with each measurement,

2. The *Condition*, C_i, under which each measurement was taken,
3. The *Observer*, H_i, the human being who made the measurement,
4. The *Time*, t_i, when each measurement was made, and, of course,
5. The *Numerical Value*, x_i, of each measurement.

This implies that, in a theoretically exact experiment, it should be possible to determine an equation:

$$x_i = f(C_i, H_i, t_i)$$

Actual experiment, however, has never been sufficiently precise to permit such determination as a general rule. Changes in conditions are not determined exactly. Even a single observer cannot be considered as a constant. For these and similar reasons, the best that can be done is to examine the repetitive series, x_i, for statistical control and use the available information, C_i, H_i, and t_i, as clues concerning the assignable causes that may be detected.

In order to be able to make valid predictions, data from a process must give evidence of statistical control. This leads inevitably to the question, "How many observations are required?" As reported in QC literature,[2] experience has shown that a sequence of at least 25 samples of four that satisfy a specified criterion for control is required to give even a preliminary basis for judging that a state of statistical control exists. To establish a satisfactory tolerence range, another QC concept, for individual measurements requires even larger sample sizes.[3,4] Thus, on the basis of QC considerations, it may be concluded that

A. Less than 100 measurements may be sufficient to disprove a *theory* or *hypothesis*, but
B. At least 100 measurements that meet a specified criterion for control are required to provide a minimum satisfactory basis for *prediction* relating to average and standard deviation.

QC Concepts Related to Analysis of Information

The concept of Statistical Control takes precedence above all others in any QC analysis of information. This assumes that a criterion of control has been established as part of accepted theory. Depending on the problem, the criterion may be any one of several possible criteria. It may even be a combination of several. In inspection work, it has been customary to rely on the use of control charts. In other applications of QC, many other criteria are used. The choice depends on the economic factors of cost and the value of finding an assignable cause. This QC concept, assignable cause, has been defined[2] as a cause "that can be found by experiment without costing more than it is worth to find it." It is obvious that many causes that would be considered assignable when determining a fundamental constant of physics or chemistry would not be so considered in controlling a manufacturing process or even in carrying out some researches or developments.

Not all possible assignable causes are known at the start of an experiment. For this reason, a suggested QC procedure is to apply a number of statistical tests to the data to detect any unknown assignable cause and to predict its nature.[3] This is also proposed as an important tool of analysis that should be applied to OR situations. A discussion of the details of such application is outside the range of this article. However, several pertinent articles exist in QC literature.[3,5,6,7]

QC has always recognized that control of quality is a cooperative venture. In production work, this has meant cooperation between inspectors and engineers responsible for making the product. Even the engineer responsible for the design must be included in the team. When the quality to be controlled is in research and development work, the team may include engineers, scientists, and statisticians. Depending on the problem, these scientists may include psychologists, econometricians, biometricians, and so on, as well as physicists and chemists. Each individual in such a team brings a knowledge of accepted theory in his own field that may help to account for assignable causes detected as noted above. In many respects, this joint or Cooperative Investigation by engineers, scientists, and statisticians is similar to what is intended in an OR investigation.

However, there is a difference in what happens at the end of the investigation. In the case of OR, the problem is often considered completed as soon as the analysis is complete and the report written or made. This is not true of QC. Finding trouble requires that action be taken. Usually, this action is initiated by the QC man himself. This means that he has a responsibility to see that he has reached the right conclusion and that the action does in fact improve quality. If it does not, it is necessary to keep looking for the cause of trouble. Thus, the inclusion of Corrective Action in the QC procedure is an important governor that has assisted in sharpening the tools of QC and might be equally useful in OR.

QC Concepts Related to Prediction

The solution of a problem is necessarily a prediction relating to it. QC has given considerable attention to the reliability of predictions. One conclusion relates to the kind of information on which the prediction is based. Stated formally

A. A *Prediction* has maximum validity only when all *Assignable Causes* relating to it are known and have been taken into account.

Thus, a prediction is meaningful in a statistical sense only when it applies to a situation that can be demonstrated to be in a state of statistical control. Since this is a condition that may not be met, QC has considered alternate situations as well.

In the design of a piece part to be used in a product, the engineer carefully specifies limits to be met by each dimension. A critical instance of this type is the design of a shaft to be used in a bearing. Ordinarily, a sloppy fit is just as important to avoid as an interference fit. Thus, from the point of view of utility, there is a desired clearance on each side of which value decreases. The engineer sets tolerance limits for individual shafts in order to limit the number of interference and sloppy fits in the assembled product. The same sort of consideration applies to the bearing as well as to the shaft. At first, it may seem that knowledge of the average and standard deviation of shaft diameters should be sufficient to assure a satisfactory product. Unfortunately, this is not so. Even if out-of-roundness is excluded, wear of tools produces nonuniform variation in the product that must be considered. For this reason, the practical average of the engineer is at best a range of averages and not a true average. This discussion leads us inevitably to the following conclusions

B. That *Prediction* relating to tolerance limits or a *Tolerance Range* for possible individual measurements is equally as important as *Prediction* relating to the location of the *Average*, and
C. That *Prediction* relating to the location of the *Average* should also be in terms of a *Tolerance Range* for an average of at most 100.

The second of these conclusions is, in effect, a limitation on what is considered an assignable cause. It rec-

ognizes that a shift in the average equivalent to one twentieth of the range between the tolerance limits will have little effect on the number of individuals found outside these limits and also would require an unduly large sample of observations to verify.

Another QC observation relating to prediction is that attention should be directed to the control of assignable causes. It is for this reason that inspectors are furnished lists of defects relating to the products that they are inspecting. These lists of defects are not static things that may be determined and then forgotten. Instead, they are simply the latest version of the troubles that are being encountered. Inspectors are expected to add items to these lists as new troubles are encountered and to omit items for which technology has found adequate answers. This leads to the conclusion

D. That the *Prediction* should make clear what independent checks should be made to assure that future measurements will have been taken under conditions appropriate to the *Prediction*, i.e., that known *Assignable Causes* have been brought under control.

SUMMARY

This article assumes that both OR and QC employ scientific method. The aim of both is to establish an economic answer. To date, QC has had its widest application in the field of manufacture or, more generally, in the field of repetitive measurement. In a restrictive sense, OR has also been applied in the field of repetitive measurement. However, where QC has usually been used to reduce variability in a given process, OR has been used to compare several processes. Both are interested in cost. In QC, it is reducing cost by eliminating assignable causes, usually in a single process; in OR, it is comparison of the costs of several processes. Both, to be well done, require the cooperation of engineers and scientists of all types.

A major difference between OR and QC is that OR seldom assumes responsibility for action while QC asumes that initiation of action is part of the job and is to be followed by monitoring the results of the action. This has helped QC to obtain a rather complete picture of the repetitive process that should be helpful to OR people. This article draws attention to certain concepts used in that picture that have possible applications in OR.

It is fundamental to QC that the solution of all problems involves a repetitive process. Even the statement of a problem is one step in such a process. Theory, hypothesis, and data change from day to day. Today's analysis differs from yesterday's. Inevitably, predictions should become more meaningful with each repetition.

Specific concepts developed from QC considerations include

1. Components of data as evidence
2. Statistical Control
3. Assignable Cause
4. Tolerance Range
5. Components of prediction with maximum validity

QC has found that each of these concepts is necessary for a complete evaluation of the repetitive process. It seems reasonable, therefore, that they should be equally important in OR considerations.

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The Master Control System In General Electric

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INTRODUCTION

Statistical Methods, one of General Electric's consulting groups, received from its manufacturing people the problem of developing a quality control system that would be instrumental in reducing manufacturing losses. This could be accomplished by designing a system for feedback of inspection data to: (a) provide a factual basis on which production foremen could act to prevent defects from happening, (b) serve as an instrument of accountability for supervision of all levels, and (c) provide an aid to judgment by the timely identification of the "vital" situations requiring action. It was further stipulated that this system should produce no or very little additional cost.

After surveying the problem, we arrived at the following four basic convictions:

1. The current statistical quality control philosophy underestimated the value of attribute data. We became convinced that more effective use could be made of attribute data if they were presented in an integrated system of control charts that were designed to pinpoint responsibility. It was observed that there is a tremendous amount of attribute data available and that, predominantly, attributes form the language used and understood by operators and foremen.

2. The system should be operated by manufacturing people, principally operators and foremen, as part of their daily routine. It should not be solely a tool in the hands of a quality control specialist whose duty is to advise the manufacturing people when and where they are out of control. To operate

effectively and efficiently, the system should be directed daily by the management of the manufacturing people.

3. To be valid in its guidance, each datum appearing in the system should have a statistical interpretation. The statistical methods of the system should be designed to function in a routine manner. To be an effective tool to operators and foremen, the data system must be simple and pin pointing; its conclusions should be apparent at a glance.
4. In order to develop a works-wide system, the component parts should be integrated. Here again, the integration must be simple and pin-pointing. The conclusions, formed by going from one control to another, should be apparent at a glance.

Following these four basic convictions, Statistical Methods, together with the manufacturing, engineering, inspection, and quality control people, is developing the "Master Control System." The "Master Control System" is undergoing a process of evolution as it is being applied to the quality problems of individual works. We feel that so far a good beginning has been accomplished and that the system as it is being presented in this article is a prototype of future systems.

In this article we shall cover the following three aspects of the system:

1. The Master Control Sheet
2. The Principle of Pyramiding
3. The Number Defective Table.

THE MASTER CONTROL SHEET

The master control sheet can be explained best by an example. Figures 1, 2, and 3 illustrate how the master control sheet functioned in a specific foreman's area of responsibility. In this application, the rejections from 100 percent inspection were assigned to the operation at fault. An hourly worker performed all the clerical work and maintained the charts, spending approximately 30 minutes per day on this chore. In Fig. 1, the percentage of daily scrap is plotted for the month prior to installation of the master control system and also for the fifth month after installation. It can be seen that a major reduction in scrap was effected. The middle line for each month is the average percentage of scrap produced during the previous month. The red line is the upper statistical limit computed about the process average and the green line is the lower statistical limit. The three lines give a graphic analysis of the radical variation of the daily scrap. It should be observed that the variation was considerable during the month of "past" data. The fifth month after installation reveals that the scrap is approaching a condition of statistical stability. There is an extreme run on the high side during the early part of the month, an extreme run on the low side during the latter part, and one point out-of-control on the low side. Charts were maintained for the foreman and for each group of operators. The entire system was installed and operated at no additional cost.

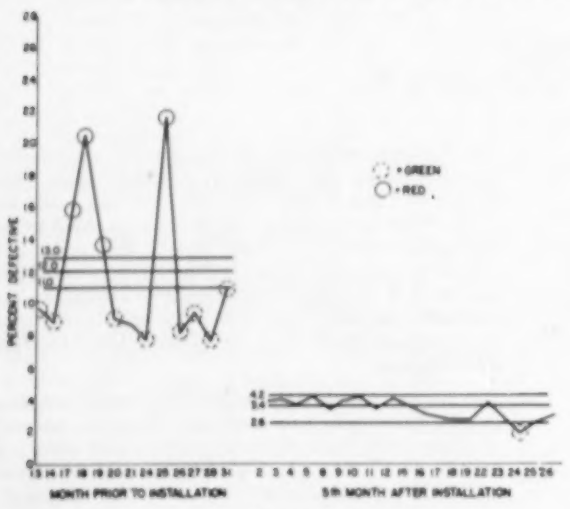


Figure 1

MONTH OF PAST DATA

P	STATION	1	2	3	4	7	8	9	10	11	14	15	16	17	18	21	22	23	24	TOTAL	P	ST'D P
1.0	CORE ASSEMBLY	25	30	40	20	27	10	54	20	5	30	40	30	20	27	6	36	36	12	14	20	(622)	0.57	0.6
0.7	SPACERS	35	30	5	21	32	34	9	1	58	20	54	5	25	28	27	9	3	3	4	8	(387)	1.06	1.0
1.2	HOT STAKE	24	15	20	20	19	20	34	18	14	23	20	11	19	25	35	20	18	11	11	16	(416)	0.37	0.4
2.6	CRIMPERS	5	6	5	6	5	5	6	5	5	6	5	6	5	6	5	6	5	6	5	6	2086	2.59	2.6
0.1	SOLDER	3	3	2	8	4	9	7	5	0	6	15	1	7	2	4	6	4	15			(43)	0.13	0.1
0.4	TERM BEND MAKER	24	29	8	7	20	29	5	32	27	20	5	22	19	26	36	29	6	5			(279)	0.79	0.8
0.7	CANNER	42	45	7	37	3	20	27	38	2	42	22	15	2	37	8	44	9	5	9	2	(415)	0.56	0.6
3.6	TERM BASE ASSEM	5	6	5	6	5	5	6	5	5	6	5	6	5	6	5	6	5	6	5	6	2982	2.51	2.6
1.8	MICA BASE ASSEM	9	20	0	20	10	1	8	2	8	19	5	1	3	5	3	5	2	8	2	8	(442)	1.29	1.2
12.0	TOTAL	172	184	92	149	129	135	156	129	68	172	157	103	106	161	129	161	88	71	45	80	(1031)	9.8	10.0
	PRODUCTION	774	795	1151	1196	1288	1210	1004	1004	1049	1151	1020	1055	1066	1196	1288	1210	1172	1172	1172	1223	11583		

GREEN
RED

Figure 2

Figure 3 shows the foreman's master control sheet for the fifth month after installation. One of the most significant features illustrated here is the increase in sensitivity gained by the breakdown of the scrap figure. Although the total is out of control only once during the month, the breakdown shows 33 out-of-control points. Any one of the nine operations could have been broken down into another classification of defects. For instance, the core assembly defects could have been broken down into their various types with a similar increase in sensitivity. A particular type of core assembly defect could again be broken down into its attributes, each of which would have a physical meaning in the line. These additional data could have been provided simply by designing an inspection code system. To provide a variable system of control equal in sensitivity would be impossible within any reasonable cost.

The value of the green circles should not be underestimated. A green circle represents a radical change that resulted in less scrap. It tells the foreman that an

5th MONTH AFTER INSTALLATION

p̄	STATION	2	3	4	5	8	9	10	11	12	15	16	17	18	19	22	23	24	25	26	TOTAL	p̄	STD p̄
0.4	CORE ASSEM	15	23	30	20	28	12	15	6	9	2	4	5	6	12	4	4	12	9		248	0.33	0.3
0.2	SPACERS	11	12	16	19	21	12	16	9	12	6	13	6	3	12	13	13	7	9	7	222	0.29	0.3
0.4	HOT STAKE	13	13	15	14	14	9	30	12	14	14	13	10	10	13	10	22	11	21	12	270	0.36	0.4
0.7	CRIMPERS	27	24	28	31	35	37	36	47	56	24	25	21	22	21	20	34	24	29	18	541	0.72	0.7
0.05	SOLDER	1				1			1	1	1										5	0.01	0.05
0.1	TERM BEND WAXER	1	5	5	3	1	3	1	1	2	4	2	2		2	3	2	2	1	1	37	0.05	0.05
0.05	CANNER	1	1		5		3			4	3	3	2			1	3	3			29	0.04	0.05
1.2	TERM BASE ASSEM	60	50	62	50	62	23	30	44	36	40	44	38	37	25	35	36	30	20	10	516	0.82	0.8
0.4	MICA BASE ASSEM	26	26	18	28	20	34	26	27	40	30	36	30	30	20	26	42	27	27	25	578	0.77	0.8
3.4	TOTAL	150	152	140	161	166	154	166	150	185	147	144	120	108	108	113	176	125	136	112	2547	3.38	3.4
	PRODUCTION	4122	3815	3815	3993	3953	3975	3975	4075	4165	3791	3827	4006	3976	3911	4066	4123	4006	4167	3464	75292		

○ = GREEN
○ = RED

Figure 3

opportunity exists to discover the cause and make it a permanent characteristic in the process. In addition to this, they have a favorable psychological effect upon the foremen and operators.

Besides pointing out to the foreman which operations are out of control on a particular day, the circling technique analyzes quality trends for him. The following five different types of trends are apparent in Fig. 3.

1. There has been a radical change resulting in more mica base assembly defects that has continued during the entire month.
2. There has been a radical change resulting in fewer terminal base assembly defects that has been maintained the entire month.
3. There has been a radical change resulting in more spacing defects during the first part of the month: this radical change has been checked and brought into control during the latter part of the month.
4. There was a radical change resulting in more core assembly defects during the first part of the month. The action that checked it was probably responsible for a new low level of defects during the latter part of the month.
5. The operations of soldering, terminal bend waxer, and canning, since they show no circles, are probably functioning within the respective capabilities of their operations. No further reductions in these operations should be expected from normal quality control efforts.

The breakdown of the p̄'s in the left-hand margin gives the foreman basic information as to where to concentrate his efforts. At the beginning of the month he could have seen that more than a third of his defects had been coming from the terminal base assembly operation. Each month all the rows are added horizontally and the p̄'s to be used for the next month calculated by dividing the previous month's production into the number rejected for each item listed. These percentages are then rounded to the nearest standard p̄ listed in the number defective table. They can be seen in the right-hand margin of the chart.

Although production had been cut since the installation of the master control sheet, the productivity per operator was materially increased because of the improvement in quality.

One of the advantages of the master control sheet is that all the information is on one sheet of paper. The human mind can grasp information from one sheet of paper much easier than information scattered on, say, nine sheets of paper. Another advantage of the master control sheet over the p̄ chart is that no difficulty is encountered from a varying n. Each entry can be checked against its exact n and circled accordingly without distorting the picture on the chart.

THE PRINCIPLE OF PYRAMIDING

The most effective way to illustrate the principle of pyramiding is to present an example from the charts forming the master control system at one of our plants.

As far as it is practical, the master control system produces a master control sheet for each person in the manufacturing organization. Charts for operators were considered impractical in this plant. Figure 4 shows the pyramid for the master control system. Charts 1 through 12 are the foremen's charts. Chart 13 is for vendor defects. Chart 14 is for defects whose sources are undetermined. Charts 15 through 18 are the charts for the general foremen. Charts 19 and 20 are for the superintendents. Chart 23 is for the plant manager, the apex of the pyramid. Number 21 is for inspection and 22 is for engineering. The foremen's totals are pyramided to form the general foremen's charts. The general foremen's totals are, likewise, pyramided to form the superintendent's charts. The two superintendent's totals and the totals for vendor defects and undetermined defects are pyramided to form the plant manager's chart.

Figure 5 shows the plant manager's control chart for September. It can be observed that the total for the plant manager is out of control on the high side for Sept. 11. This could be rapidly traced down through the pyramid to the six principal defects at fault simply by following the red circles. Figure 6 shows the excerpts from the master control system that pin-point these six causes.

The lower the level of the chart in the pyramid, the more sensitive the control becomes. Hence, the men who need to take action have the pin-pointing information to guide them daily. The higher the level in the pyramid, the more detail is eliminated; but the out-of-control conditions which are revealed are more important. The charts are so directly connected to each other that the entire mass of data directly below a person in the pyramid becomes easily and immediately available to him at his discretion.

The importance of each superior discussing each circle on his chart daily with the subordinates concerned cannot be over-emphasized. Any person in the pyramid can activate that portion directly below him by following this rule. A plant manager thus devoting a few minutes per day, can be assured that all the men in his organization are regularly investigating and taking action on the out-of-control conditions that are indicated by their respective charts.

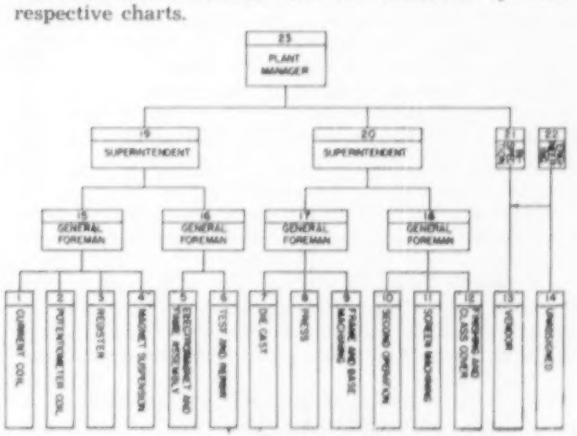


Figure 4

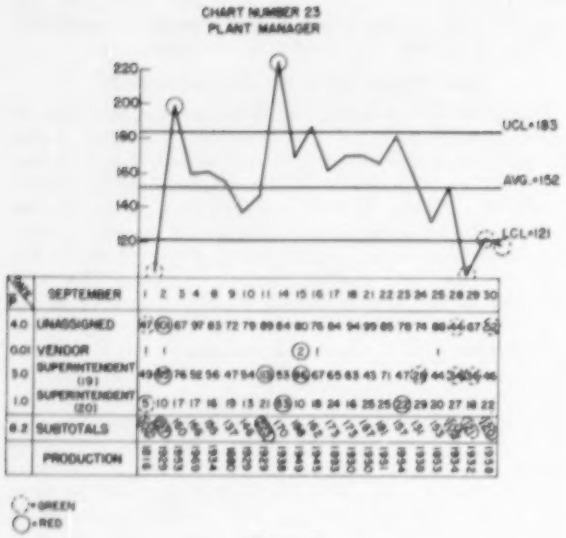


Figure 5

During the first year of using the master control system, this plant realized a 40 percent reduction in manufacturing losses as compared to their best previous year. This is a reduction, on a yearly basis, of over $200,000. Contrary to their original thoughts, the inspection expense, including quality costs, actually dropped rather than increased. The first year's savings on this item alone was $76,000. Best of all, there was no accompanying deterioration in quality of the final product.

THE NUMBER DEFECTIVE TABLE

It was initially recognized that it would be impractical to teach operators and foremen statistical mathematics and expect them to compute the limits for the data relevant to their operations. Consequently, the number defective table was compiled to overcome this obstacle. The statistical limits for an attribute characteristic can be found in the table by entering it with the percent defective representing past performance and the number of units inspected.

The binomial distribution was used to compute the limits. The number defective formula, $\bar{pn} \pm 2.58 \sqrt{\bar{pn}(1-\bar{p})}$, was used so that the limits would be expressed as the number of defective units rather than the percentage of defective units. This was desirable since it facilitated use with the master control sheet. It should be observed that 2.58 σ was used rather than the customary value of 3.00 σ. Observing that only 0.7 percent certainty was lost and that the sensitivity gained was 0.84 σ, Statistical Methods decided to standardize on the 99 percent limits represented by 2.58 σ rather than the 99.7 percent limits represented by 3.00 σ. The number defective table gives limits for 86 different values of $\bar{p}$ and 130 values of n. Interpolation may be used for intermediate values if greater accuracy is desired since the number defective formula is approximately a linear function.

An excerpt from the number defective table is presented in Fig. 7. Consider as an example a process average of 5.6 percent and an n of 280. The limits of 5 and 26 are shown in bold type in the column headed 5.6 and the row 280.

Two forms of the number defective table are used. A large single sheet has proved more popular in the factory; the pamphlet form is easier to use at a desk. Instructions for using the number defective table are given on the first page of the pamphlet form.

A problem sometimes encountered in using the number defective table is how to obtain limits when the $\bar{p}$ and n values are off the table. The following techniques have been developed and recommended by Statistical Methods. The $\bar{p}$ and n in the number defective formula $\bar{pn} \pm 2.58 \sqrt{\bar{pn}(1-\bar{p})}$ are present as a product term $(\bar{pn})$. Consequently, one may enter the table with any combination of p and n whose *product* is the same as the actual $\bar{p}$ and n for which limits are being sought. Some error is introduced by not changing the $(1-\bar{p})$ term; but, for most practical uses, this error is of no consequence. The following examples are offered to illustrate this point for a $\bar{p}$ of 50 percent and n's of 100, 1000 and 5000. It should be noticed that the slight error introduced by this technique has the effect of widening the limits.

Limits Wanted for	Correct Limits Using the ND Formula	Using These Altered Values of p and n	These limits are obtained from ND Table
n = 100 $\bar{p}$ = 50%	37 63	n = 200 $\bar{p}$ = 25%	34 66
n = 1,000 $\bar{p}$ = 50%	459 541	n = 2,000 $\bar{p}$ = 25%	450 550
n = 5,000 $\bar{p}$ = 50%	2408 2592	n = 10,000 $\bar{p}$ = 25%	2388 2612

This method is recommended for values of $\bar{p}$ up to 50 percent. When higher values of $\bar{p}$ are needed, it is recommended that the percent effective, $\bar{p}'$, where $\bar{p} = 1-\bar{p}$, be used to obtain the limits. The lower limit for the Number Effective would be subtracted from n to obtain the upper limit for the Number Defective; similarly, the upper limit for the Number Effective would be subtracted from n to obtain the lower limit for the Number Defective.

Figure 6

The following example for $\bar{p} = 80$ percent and $n = 1{,}000$ illustrates this usage:

	ND Formula		Number Defective Table	
	Correct Limits for No. Defective		Limits for No. Effective	Limits for No. Defective
$\bar{p} = 80\%$ $n = 1{,}000$	767 833	$\bar{p}' = 20\%$ $n = 1{,}000$	167 233	767 833

Although the number defective table was computed from the binominal distribution, it can be used to obtain the limits for the Poisson distribution. It was observed that the only difference between the Poisson formula for number of defects ($un \pm 2.58 \sqrt{un}$) and the binominal formula $\bar{p}n \pm 2.58 \sqrt{\bar{p}n(1-\bar{p})}$ is the term $(1-\bar{p})$. (The symbol u is defined as the number of defects per unit, the number of defects in a sample of n units divided by n. Hence $\bar{u}$ is defined as the average number of defects per unit.) Consequently, for low values of $\bar{u}$, the difference in limits is negligible. The technique is to enter the number defective table in a manner that minimizes the value for $\bar{u}$. The same method is used that was described above to obtain limits for $\bar{p}$'s and n's that were off the table. Ironically, with this approximation, the number defective table provides limits that are more accurate for the Poisson distribution than for the binominal distribution on which it is based. The following examples, $\bar{u}$'s of 0.05, 0.5 and 5 and n's of 100, illustrate the use of the table in obtaining Poisson limits:

Limits Wanted for	Correct Limits Using u Formula	Using These Altered Values for u & n	These limits are obtained from the ND Table
$\bar{u} = 0.05$ $n = 100$	— 11	$\bar{u} = 0.005\,(0.5\%)$ $n = 1000$	— 11
$\bar{u} = 0.5$ $n = 100$	31 69	$\bar{u} = 0.005\,(0.5\%)$ $n = 10{,}000$	31 69
$\bar{u} = 5.0$ $n = 100$	442 558	$\bar{u} = 0.05\,(5.0\%)$ $n = 10{,}000$	443 557

Thus, by providing operators and foremen with copies of the number defective table and instructing them in its use, we enable them to examine statistically their attribute data without the necessity of learning statistical mathematics or computing the limits.

P% / N	5.0	5.2	5.4	5.6	5.8	6.0	6.5	P% / N
250	3 22	3 23	4 23	4 24	4 25	5 25	6 27	250
260	3 23	4 23	4 24	4 25	5 25	5 26	6 28	260
270	4 23	4 24	4 25	5 25	5 26	6 27	7 29	270
280	4 24	4 25	5 25	5 26	6 27	6 28	7 29	280
290	4 25	5 25	5 26	6 27	6 28	6 28	8 30	290
300	5 25	5 26	6 27	6 28	6 28	7 29	8 31	300
310	5 26	6 27	6 28	6 28	7 29	7 30	8 32	310
P% / N	5.0	5.2	5.4	5.6	5.8	6.0	6.5	P% / N

Figure 7

A problem that has not been covered thus far in this article is how to pyramid data in a plant that manufactures a large variety of products.

The expected number of defects, c, can be ascertained each day by multiplying the $\bar{p}$'s by their respective production totals and adding the resulting products. Mathematically this can be shown as $\bar{c} = \bar{u}n = \bar{p}_1 n_1 + \bar{p}_2 n_2 + \bar{p}_3 n_3 + \ldots$. The expected number of defects would then be divided by, for example, 10,000, and the number defective table entered with an n of 10,000 and the corresponding $\bar{u}$. For example, assume a c of 500 is obtained. This figure would then be divided by 10,000 to obtain a $\bar{u} = 0.05$. The number defective table would be entered with $\bar{u} = 0.05$ and $n = 10{,}000$ to obtain limits of 443 and 557.

Process averages from previous data would not be used for the $\bar{c}$'s since they would vary daily with the product mix.

Local Section News

". . . BUT NOT FORGOTTEN"

BIRMINGHAM Mr. Daniel A. Preston, Rudisill Foundry, Sylacauga, Ala., presented a talk on "Quality control administration" which contributed to one of the section's most successful recent programs. His long experience in teaching Industrial Engineering and Management and his extensive consulting work in organizing and installing quality control departments provided many interesting illustrations.

BUFFALO The joint meeting with the Buffalo-Niagara Chapter of the American Statistical Assoc., at which time Dr. W. J. Youden of the National Bureau of Standards gave a very interesting

talk, was so well attended that another such meeting is planned for the coming year.

COLUMBUS Mel Lindner, Industrial Engineer, Container Div., Owens-Illinois Glass Co., presented an interesting talk on sampling plans. This talk dealt chiefly with the development and interpretation of operating characteristic curves. Prior to the meeting, the members took a tour of the local plant of the Kimble Glass Co., an Owens-Illinois subsidiary, who were the hosts.

MICHIGAN Forty-four representatives of a wide variety of industries attended the training course in Quality Control by Statistical Methods held at the University of Michigan from Aug. 17-27. The regular classes were conducted by Dr. C. C. Craig and Dr. E. C. Yehle of the University of Michigan; Dr. Irving W. Burr, Purdue University; and Dr. Edwin G. Olds, Carnegie Institute of Technology. Supplementary talks were presented by guest speakers, including: Charles W. Quillen, Ford Motor Co.; Deland H. Davis, General Foods Corp.; and Leo Herrington, King Seeley Corp.

A 30 hour training program, entitled "A basic course in statistical controls," is being held under the sponsorship of the section. The course is being conducted from 7-10 pm in the Veterans Memorial Bldg., Detroit and will continue through Dec. 13. Instructors include Dr. E. C. Yehle, University of Michigan; Harmon S. Bayer, Quality Control Consultant, Detroit; and Wm. E. Courtright, Andrew Procassini, Raymond L. Clark, Argus Cameras, Inc., Ann Arbor.

MILWAUKEE On Aug. 16, approximately 40 members turned out for a "Lick 'em and stick 'em" meeting. At this meeting 20,000 programs for the 10th Midwest Quality Control Conference were addressed. With heavy eyes and sticky tongues, the Midwest Conference is on its way. If you haven't received your program, write to Dale A. Cue, A. O. Smith Corp., Milwaukee 1, Wisconsin.

Ye shall have a year book! Irv Schoeninger and his yearbook committee of Milwaukee section members held their first meeting on Aug. 31 to organize and work on the first consignment of membership data which is being sent to them by the New York office.

NEW HAVEN On Aug. 8 the regular monthly executive committee meeting was held at the home of technical aids chairman Welton D. Parker. The program of meetings for the coming season, including speakers, clinic sessions and plant tours was presented and accepted by the committee. Plans for the educational program were also discussed.

PHILADELPHIA At present, the section is supporting and publicizing courses offered at Villanova University, University of Pennsylvania, Temple University, Drexel Institute, Rutgers University, LaSalle College, St. Josephs College, and about 10 in-plant training courses.

PITTSFIELD The executive committee held four meetings during the summer and the program for the year has been set up. A drive is planned to gain new members and secure renewals. In addition, the members were polled to aid in planning an educational program.

RHODE ISLAND The September meeting was unusually successful. Dr. J. M. Juran spoke to a full house on the subject "The top executive's responsibility for quality." The talk was well received. The turnout for this meeting was in part due to the publicity stunt of requiring complimentary tickets for admission. Each member was mailed three tickets and requested to bring two friends. It worked.

ST. LOUIS Early this month, the section and the Chamber of Commerce of metropolitan St. Louis began a training course in quality control at the Hotel Sheraton. The course will run thru Dec. 16. Late starters get further information by writing or calling E. Harvey Barnett, 1800 So. Second St., St. Louis 4, Mo. Mr. Barnett's office phone is Main 1-4000 Station 3556.

SAN BERNARDINO Dale Lobsinger, United Air Lines, Denver, Colo., speaking on the subject, "Quality control in airline operations," was the principal speaker at the kick-off meeting of the section. Sixty-five members and guests enjoyed the fine presentation. Guests included a delegation from the Controllers Div., Norton Air Force Base, San Bernardino.

SAN FRANCISCO BAY AREA The section is proud to announce the formation of the Sacramento subsection with a total membership of 24 persons. Officers elected at the organizational meeting were Jack Hovermale, Chairman; Edwin S. Hodges, Vice Chairman; and Jeannette Ashton, Secretary.

The subsection was organized in order to better serve the interests of members in the Sacramento area, which is about 80 miles from San Francisco. This made active participation in the Bay Area section difficult for these members.

Members of the subsection have already embarked on an active program of dinner meetings and a vigorous membership drive to attract new members. We are confident that they will assume full section status and responsibilities in the very near future.

SOUTHERN CONNECTICUT The evening of Aug. 25 will long be remembered, as Mr. I. L. Hartenberg, President, Metalix Mfg. Co., Norwalk, and his wife played host to the officers and executive committee of the section. The event was the annual summer dinner meeting. The place was the Birchwood Country Club, Westport. The special invitation guests were the wives of the committeemen. This was an excellent opportunity for the ladies to become acquainted with each other and to meet the fellows who work hard at the administration of the section.

Dinner was served at 6:30 pm and at 8 pm, the business meeting was held. While the men were diligently at work planning the future of the section, the ladies enjoyed a social evening together.

The section executive committeemen and their wives gave a big vote of thanks to Mr. and Mrs. Hartenberg, our hosts for the evening, as it was a night long to remember.

TOLEDO The annual spring social event for the section was held at Devil's Lake, Michigan, with the M&S Mfg. Co. acting as hosts. At that time, the newly elected officers for the coming season were introduced.

WESTERN MASSACHUSETTS The membership, program and educational committees of the section met early in August and have formalized their plans for the coming season to the extent that the membership committee is actively engaged in following up on old membership and renewals and are also combing the surrounding industry for prospective members. As to the program committee they have finalized their work and it appears that there will be six technical meetings and one social meeting during the season.

The education committee has organized an intermediate course in conjunction with American International College.

WINNEBAGO The nominating committee met at a meeting called by Chairman Ray Hollands, Marathon Corp. A slate of candidates was drawn up and submitted to the members for their approval. The ballot contained the following names: Elvin G. Powells, Chairman; Lee Manders, Vice Chairman; Edward Schuch, Secretary; Paul Ebert, Treasurer. The ballot was also left open for any nominations by the members.

". . . CAST THEIR SHADOWS BEFORE"

ALBANY The Nov. 10 meeting will feature William E. Masser, manager of quality control engineering for the Mfg. Services Div., General Electric Co. of Schenectady, New York. Mr. Masser will present "What management expects of quality control engineers." In his presentation he will discuss managements' methods of measuring the effectiveness of quality programs, and investigate the aspect often glossed over, the cost of quality. Mr. Masser was general chairman of the 1953 National Convention held in Philadelphia.

BIRMINGHAM J. A. Davies, supervisor of statistical control methods, Electronics Div., General Electric Co., Owensboro, Kentucky, will be the speaker at our meeting on Nov. 10. Mr. Davies' subject will be "Variables sampling without calculations." The public is welcome.

BUFFALO The 1955-56 program will be launched by a social evening which will be made attractive to the ladies. A plant tour through the Dunlop Tire & Rubber Co., arranged by our own Mr. W. Irvine, should bring out a good size crowd at our November meeting.

One of the highlights of the season will be the joint meeting with the Technical Societies Council in which the section will sponsor Dr. Brumbaugh. This is a February meeting and more information will be made available at a later date.

BURLINGTON The next meeting will be held at Rutland, Oct. 19. The afternoon program will be an educational seminar intended for new members. Sessions will be conducted by Chet Gadzinski, General Electric Co.; Richard Hooley, University of Vermont; and Carlton Murphy, National Carbon Co. The evening speaker will be Leonard A. Seder, QC consultant.

Again this year there will be no regular November meeting of the section. In its place, many members will be attending the Ninth New England Quality Control Conference, Nov. 3-5, to be held at the Hotel Statler, Hartford, Conn.

CLEVELAND The next meeting will be on Nov. 4 at the Cleveland Engineering Society. Dr. Acheson J. Duncan, John Hopkins University, will speak on "Economical design of control charts."

COLUMBUS The 1955-56 program has been built on the theme "Quality control in action." Each month a local manufacturing concern will serve as host and provide a speaker whose topic will be concerned with the solution of a problem in their particular industry. The October meeting will be held on Oct. 19 at Ohio Gear and Axle Co., Newark, Ohio.

DANVILLE -SUNBURY The October activity of the section will feature a joint meeting with the Williamsport section of the Institute of Radio Engineers. This gathering will be held on the Bucknell Campus at Lewisburg, Oct. 19.

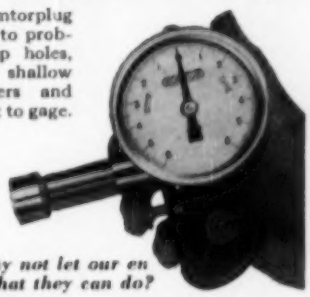
ERIE On Nov. 9 Mr. Stan Jacke, electronics engineer of the Detrex Corp., Detroit, Mich., will present "Decontamination by means of ultra-sonic cleaning." The Detrex Soniclean process will be demonstrated.

HARRISBURG At the November meeting, Mr. William MacCrehan, quality engineer, Bendix Radio Div., Bendix Aviation Corp., will have for his topic, "QC at work."

(Continued on page 26)

SPECIAL Internal Gaging Problems are often easily solved by this gage

With slight modifications Comtorplug often is the simplest solution to problems of gaging splines, deep holes, spherical bores, blind holes, shallow holes, counterbores, shoulders and other bores considered difficult to gage.



If you have a "toughie", why not let our engineering department see what they can do?

COMTORPLUG with interchangeable expanding plugs to gage simple or special bores from 1/8" to 8" dia.

UNIQUE ADVANTAGES

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- Shallow holes, deep holes, inside splines, open-end holes gaged easily.
- Detects ovality, back or front taper, bell mouth, barrel shape.
- Reaches to bottom of blind holes.
- Gages work while still held in chuck.
- A shop tool for all-day every day use.
- Portable—no wires, hoses or stands.

Investigate the gage used by the thousands in jet engine, guided missile, farm machinery, automotive transmission, household appliance, and other volume-precision plants. IT MAKES PRECISION GAGING EASY . . . at machine . . . at inspection bench . . . for selective assembly. No other like it—investigate and see why.

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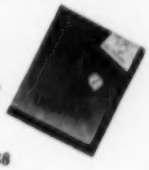

GET THE FULL FACTS — REQUEST BULLETIN 48

The Inspector begins
by taking 24
samples every hour . . .

From the

CRIBBAGE BOARD

The accompanying series of pictures show how one company found a novel way to provide control chart information at the machine. Doug Potter, (now deceased), Chief Inspector, Ken Cook, Quality Control Engineer, and Jim Phelan, Inspection Foreman, of the Thomas & Betts Co., Inc., manufacturers of electrical fittings in Elizabeth, N. J., put their heads together and came up with an idea they christened "cribbage board quality control." The pictures tell the story.

However, by way of background, Inspection and Quality Control at T & B have been covering these same jobs for several years on a sampling inspection basis, maintaining control charts on them in the inspection office. It was clearly recognized, however, that failure to get this information before the operating people was the missing link in the company's quality control program.

But how to do it?

Control chart concepts were familiar to the inspection and quality control staff, but operating personnel were not "in the know" and hence there was the usual problem of getting acceptance by the shop of control charts at the machines. Further, the very nature of the machines and operations to be covered made it virtually impossible to maintain conventional charts laid out in the usual way on graph paper.

Then
measured . . .

Finally the results
Cribbage Board

As long as the pegs
stayed in the green,
Everyone felt serene . . .

QUALITY CONTROL

The first problem was solved by providing a brief in-plant training course for operators and set-up men. These sessions were devoted to discussion of quality problems, shop procedures, and simple bead demonstrations and case history reports and charts from inspection files to put across the function of a control chart as a dependable device for telling when to leave a process alone and when to take corrective action.

The cribbage board charts solved the second problem. They fit in admirably with the physical equipment in the shop, are clearly visible to all concerned, and are very simple to maintain. They summarize at the machine the more detailed record and charts maintained in the quality control office on these same jobs. The green (acceptable) and red (unacceptable) bands have been set up to guide the maintenance of quality levels known to be attainable from past records and which represent current economic levels of operation.

Dick Thompson, T & B's technical writer, prepared these photographs and captions as a display on the company bulletin board near the time-card rack, and posted the display at the time the "charts" were placed on the machines. Reception has been excellent, and expansion of the cribbage board quality control program is going forward very satisfactorily.

The samples are washed . . .

and the results entered on the Inspection Charts

are posted on the for the operator.

But when the peg landed in the red, "Stop the Machine! Change Dies," she said.

(Continued from page 23)

KANSAS CITY Parke Carroll, vice president and business manager of Kansas City Athletics Inc., will be the guest speaker at the November meeting. The dinner will be Wednesday night, Nov. 9 at the Blue Hill Restaurant. After the dinner and business meeting, Mr. Carroll will talk on "The statistics, promotion and organization of a major league ball club."

MICHIGAN Here are some highlights of the coming meetings of the section. On Oct. 19 at the Dow Chemical Co., Midland, Deland H. Davis will talk on "Quality control in chemical processes."

A 5 pm and an 8 pm session at the Science Hall, Wayne University, Detroit is planned for Oct. 21. The early session will feature Dr. E. C. Yehle who will present "Testing the fit of theoretical distribution." This is an advanced technical session. The evening's program is "Natural tolerance limits from a normal distribution" to be presented by Dr. Phillips Whiddem.

Harmon S. Bayer, QC consultant, Detroit, will present "Quality capability studies" at our Nov. 4 meeting which will be held at the Post Cereals Club House, Battle Creek.

Nov. 10, at the General Motors Institute, Flint, Clarence R. Burdick, Houdaille-Hershey Corp., Detroit will talk on the subject, "Quality control—now and the future."

The Rackham Bldg., Ann Arbor, is the place to go on Nov. 18. Mr. N. L. Jones, general supervisor of statistics, Illinois Bell Telephone Co., Chicago, will present "Quality control applied to accounting."

MILWAUKEE The section will not hold a regular meeting in November. Reason—everyone is going to the 10th Anniversary of the Midwest Conference on Thursday and Friday, Nov. 17-18, at the Hotel Schroeder in Milwaukee. This is a conference you can't afford to miss. The host section will be waiting for you at the pre-convention social at the Pabst Blue Ribbon Hall.

MINNESOTA Mr. Dorian Shainin, Vice President of the Society, will be the guest speaker at the Nov. 10 meeting. His subject will be "100% inspection—its strength and weaknesses."

MUNCIE Mr. E. H. Robinson, Director of Quality Control, Johnson & Johnson, has been scheduled as the speaker at the third meeting of the season to be held on Nov. 10. His topic will be on a fascinating new field of statistical application, "The use of statistical techniques for making adjustments in production planning to correlate with changes in sales trends."

NEW HAVEN On Nov. 8 the third regular monthly meeting will feature as guest speaker, James L. Dolby, project engineer of General Electric Co., Schenectady, N. Y. His topic will be "Engineering for inspection."

NORTHEASTERN INDIANA A dinner meeting is planned for Nov. 10 at 6:30 pm at the Plantation, Auburn, Ind. The guest speaker will be Wendell Phillips, QC manager, Ford Tractor & Implement Div. The dinner meeting tickets are $2.00 and the meeting is opened to all those interested in quality control. The Warner Automotive Div., Borg-Warner Corp. will be host to an after dinner plant tour. Reservations can be made with the treasurer, H. Paul Koogle, General Electric Co., 1635 Broadway, Ft. Wayne.

PHILADELPHIA Roger Craine, director of operations research, Westinghouse Brake Co., will discuss "Industrial applications of operation research" at a meeting to be held on Oct. 21 at Franklin Institute.

Franklin Institute will again be the site of our Nov. 18 meeting at which time Dr. J. M. Juran will offer "A blueprint for installing a quality control program."

PITTSFIELD The section announced an all day educational clinic to be held at the Stanley Club, Pittsfield, on Oct. 28. "Management and quality costs" will be the theme of the session. Speakers will be William Masser and Fred Burkenkamp of General Electric. The session will begin at 9:30 am and finish at 4:30 pm. This is the first of two all day clinics run each year by the section.

RHODE ISLAND Our speaker for October will be Axel Sternloff of the American Steel and Wire Co., Warren Cable Div., Worcester, Mass. Mr. Sternloff teaches at Worcester College, is a member of ASTM, is a past chairman of the section, and was chairman of the Sixth New England Quality Control Conference. His subject will be "Deviations."

ST. LOUIS The second fall meeting will be held at the Chouteau House, Washington University, on Oct. 21 beginning at 8 pm and will be preceded by a social gathering and dinner. Henry J. Jacobson of Schaible Co., Cincinnati will present "Quality control by infiltration."

SALT LAKE CITY This section will hold a meeting on Oct. 27. Mr. G. G. Parkin, Minnesota Mining and Manufacturing Co., St. Paul, will talk on "Tests of significance in industrial processing."

SAN BERNARDINO David A. Hill, director of quality control, Hughes Aircraft Co., Culver City, is scheduled as the main program speaker for the October meeting. Mr. Hill, who will speak on the subject, "Parts vs. systems," is District #16 National Director of the Society. Mr. Hill will be assisted by Dean Voegtlen, also of Hughes Aircraft.

SOUTHERN CONNECTICUT Sherman Kingsbury, a mathematician with Arthur D. Little Inc., Cambridge, Mass., will be speaker on the night of Nov. 9, which is our big management night.

Mr. Kingsbury's subject will be "What operation research means to you." This will be first hand information from a man who has, from its beginning, been associated with the business and industrial application of these powerful tools. This will be a rare opportunity for top management to learn the facts about these techniques from a representative of one of the nation's oldest and best reputed business consulting firms.

The section is looking forward to this annual management night. In the past, this has been a well attended meeting with many of the executives and top level people of the industries in this area as guests. Having Mr. Kingsbury as our speaker of the evening and with his background in production, scheduling, inventory control, and evaluation of industrial research programs, attendance should far surpass past meetings of the section.

The meeting will be held at the Stratfield Hotel, Bridgeport. Dinner will be at 6:30 pm with the meeting getting underway at 8 pm.

TOLEDO Our first plant trip of the new season will be at the Whirlpool Co., Clyde, Ohio on Oct. 20. The group will travel by bus to Clyde and a box lunch will be served during our visit at the plant.

TORONTO At our next regular meeting to be held Nov. 2, our guest speaker will be W. D. Davidson, B. N. A. Holdings Ltd., Toronto. His subject will be work samplings.

On Nov. 16, a plant visit to Canadian Industries (1954) Ltd., Paint & Varnish, Division is planned. Members will be given full information regarding the plant visit at a later date.

WESTERN MASSACHUSETTS The second meeting of the year will be held on Oct. 18 in the Sheraton room of the Sheraton-Kimball Hotel, Springfield. The meeting time will be 8 pm wherein Frank Cottadel of the Traveler's Insurance Co. will speak on the subject of risks encountered in insurance underwriting.

WINNEBAGO Tentative plans are being made to make the November meeting one to remember. This will be our first anniversary and calls for a large affair.

WORCESTER Mr. Roy G. Volkman of the U. S. Rubber Co., Providence, R. I., will be the speaker at the Nov. 17 meeting. His subject will be on an acceptance control chart.

"AS YE SOW . . ."

BIRMINGHAM The section is co-sponsoring a one-day clinic to be held in Chattanooga on Nov. 4 in collaboration with the Tennessee and Chattanooga sections. Any inquiries may be addressed to Howard Withers, Alabama By-Products Corp., Birmingham, who is a member of the Clinic's General Committee.

BURLINGTON Richard Hooley of the University of Vermont, Department of Commerce & Economics, will present an original talk on "Testing significance in attribute measurements of aircraft castings" at the Ninth NEQC Conference at Hartford, Conn. to be held in November. Mr. Hooley is chairman of the Burlington section's technical committee.

CHICAGO The annual two-day work shop jointly sponsored by the section and the Chicago Assoc. of Commerce and Industry together with the 10th Midwest Quality Control Conference will be held in Chicago at the Hotels Sherman and LaSalle on Nov. 7-8. The teaching staff is headed by Professor Lloyd Knowler of Iowa and includes Irving Burr of Purdue, John Henry of Illinois, and Gayle McElrath of Minnesota. The luncheon on the 8th promises to be the grand climax for the session. The chief executive officer of a large corporation in Chicago will speak on the subject of "What quality control does for industry." If past performances are any indication of the success of this conference certainly we have every right to be quite enthusiastic about it.

CLEVELAND Plans are now complete for the Cleveland Section's Second Annual Conference on Nov. 1 at the Hotel Carter. An outstanding program featuring nationally known speakers in twelve technical sessions has been prepared. The conference also includes a luncheon and banquet. Further details can be obtained from Howard Schmidt, Aluminum Company of America, 2210 Harvard Ave., Cleveland 5, Ohio.

10TH MIDWEST QUALITY CONTROL CONFERENCE The 10th anniversary of the Midwest Quality Control Conference will be in Milwaukee, Wisconsin at the Hotel Schroeder Nov. 17-18. Four concurrent series will be offered in the areas of quality control applications, related applications, brewing and malting, and pioneers.

"Pioneers" refers to six of the nation's most widely known pioneer quality control educators who, for the first time in the history of the Midwest Conference, are taking over a complete clinical series in which each of them will talk about a quality control subject of his own choosing. This will be followed by a panel discussion on the subject, "What's your problem?" The panel will consist of these same pioneers, Irv Burr, Cecil Craig, Jack Henry, Lloyd Knowler, Ed Olds, and Mason Wescott. This is a treat that comes once in ten years.

Another first for a Midwest Conference is the series of five clinics devoted to SQC in the brewing and malting field.

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1955-1956 LOCAL SECTION OFFICERS

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Denver	Elroy J. Flaten Rocky Mt. Arsenal	Loren L. Straw	Jack Schulz	
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Gr. Muskegon	Glenn A. Bailey American Coil Spring Co.	Charles C. Duff Anaconda Wire and Cable Co.	Raymond V. Porter Muskegon Piston Ring Co.	Charles R. Wainwright Sealed Power Corp.
Hamilton	Marjorie M. Baskerville Dominion Foundries and Steel Ltd.	H. E. Markle Leland Electric Canada, Ltd.	C. W. Royal B. Greening Wire Co.	A. S. Mitchell Steel Co. of Canada, Ltd.
Harrisburg	Daniel Meckley	Miles H. Nolte ALCOA	C. William Brosey Aircraft-Marine Products, Inc.	Herbert Puschner
Hartford	Chester B. Govang Gray Mfg. Co.	James Hopper, Jr. Pratt & Whitney	John H. Grady	Harold L. Hamilton United Aircraft
Huntsville	W. E. Gibbons	Verne H. Reckmeyer Thiokol Corp.	William B. Harrell	
Indianapolis	Claude B. Adair Western Electric	William C. Vissing Ely Lilly & Co.	Kermit L. Flanagan Linde Air Products Co.	Thomas E. Turner Diamond Chain Co., Inc.
Iowa	H. Ray Turney Solar Aircraft	Herschell R. Harrison Collins Radio Co.	Carroll C. Heldt Sheaffer Pen Co.	
Japan				
Kansas City	Hugh A. Springer	Glennon M. Putthoff	Vivian L. Crawford	Ivan R. Davis
Lansdale	James Bedwell	William R. Stout Hunter Spring Co.	Leroy Hendricks U. S. Gauge Co.	
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Louisville	Faye E. Smith	Harry E. Stewart	Allen D. Greene, Jr.	Raymond M. Donnelly U.S.N. Ordnance
Los Angeles	Frank H. Squires Lear, Inc.	Leslie W. Ball	David C. Saunders	Halmond L. Parks
Metropolitan	Robert R. Fero Lily Tulip Cup Corp.	F. Bruce May Johnson & Johnson	Paul H. Chook City College of New York	Edwin Shecter Sonotone Corp.
Mexico City	Elias D. Hernandez	Jose Romero B.	Carlos Reyes C.	
Michigan	Dr. W. D. Baten Mich. State Univ.	Dr. E. C. Yeble Univ. of Michigan	Stephen J. Adams Wolverine Tube	Thomas J. Anderson
Mid-Hudson	Arthur B. Guldenschuh, Jr.	James D. Lockhart Western Print. & Litho.	John Losee	Davis Gale
Milwaukee	Arnold E. Jakel Consultant	George I. Craycraft The Midland Co.	Larry K. Neuman Miller Brewing Co.	Clarence P. Dewus International Harvester Co.

1955-1956 LOCAL SECTION OFFICERS (Cont.)

SECTION	CHAIRMAN	VICE CHAIRMAN	SECRETARY	TREASURER
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New Haven	Robert I. Callahan Revere Corp. of Amer.	Gerald J. McVay Armstrong Rubber Co.	Arthur A. Stolzenberg Safety Car Heating & Lighting Co., Inc.	Jack D. Bradshaw Bradley Laboratories, Inc.
N. E. Indiana	Morton G. Pugh General Electric Co.	Donald Hensel Salisbury Axle Co.	Otto E. Schlink, Jr. International Harvester Co.	Paul H. Koogle General Electric Co.
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Rockford	Vernard Peck Elco Tool Co.	Norman St. John Woodward Governor Co.	Edward J. Rupert Ipsenlab of Rockford, Inc.	
St. Louis	Joseph Movshin Ramsey Corp.	Milton Weiss Alco Valve Co.	William H. Von Meyer Berry-Wehmiller	Samuel H. Huston
Salt Lake City	Wm. A. Hoagland Hill AFB	Osmund L. Harline	Leon K. Nelson	Sydney H. Drummond
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San Bernardino	Jordan A. Engberg Norton AFB	Harold R. Batchelor General Electric Co.	James A. Butcher Convair Corp.	Irwin A. Spitzer Kaiser Steel Corp.
San Diego	Bern R. Swarts	Langford L. Brown	John M. Janssen Pacific Alloy Engineering Corp.	Carl P. Caster
San Francisco	G. J. Lieberman Stanford Univ.	Allan M. Hull United Air Lines	Byron L. Blakeman	Stanley W. Meyer
Scranton-Wilkes Barre	Joseph A. Gallagher	Carl D. Larson	Thalia Snyder	Edward J. Baker
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South Bend-Mishawaka	Vincent A. Nichols Bendix Aviation Corp.	Gordon C. Kennedy	R. B. Boaz Bendix Products Div.	C. M. Makowsky
S. Texas	J. H. Moyer Champion Paper Co.	E. S. Aldredge	J. C. Dickson	Robert C. Ellis Continental Can Co.
S. Connecticut	Edward W. Demers Metalix Mfg. Co., Inc.	Eugene V. Grumann Buliard Co.	Nicholas Parahus P. M. Industries, Inc.	Edgar W. Dawes Allison Co.
S. Tier	Thomas H. Johnston	Theodore N. Lemoncelli	Gordon S. Lucas	Robert R. Kiely
Syracuse	Robert Hofstead Bristol Laboratories, Inc.	Richard W. Holmes Carrier Corp.	George Endrich General Electric Co.	Albert Edgar Bristol Laboratories
Tennessee	R. L. Murray Hardwick Mills, Inc.	Prof. R. M. LaForge Univ. of Tennessee	R. E. Rinella Proctor & Gamble Defense Corp.	M. T. Giachino Grace Chemical Co.
Toledo	Keith L. Lewis M & S Mfg. Co.	William W. Pound	Hilton C. Fetting Libbey Owens Ford Glass Co.	David A. Hettel
Toronto	R. Cardno Canadian General Electric Co.	D. A. Irwin Canadian Arsenals, Ltd.	B. G. Graham Canadian Arsenals, Ltd.	M. J. O'Callaghan De Haviland Aircraft of Canada, Ltd.
Trenton	John Marck Amer. Steel & Wire	Eugene B. McBride Baldwin Hill	Samuel B. Prellwitz Fairless Works	Carl W. Banks Crescent Wire Co.
Tucson	D. Hawks, Jr. Hughes Aircraft Co.	Stanley N. Ceizyk Hughes Aircraft Co.	Roy P. Palmer	Jack L. Taylor Hughes Aircraft Co.
Univ. of West. Ontario	Maurice D. Nicholson Timken Roller Bearing Co.	D. L. Robinson Standard Tube & T.I., Ltd.	Herbert A. French Dominion Woollens & Worsteds, Ltd.	E. O. Boddy Merchant's Rubber Co.
Utica	George V. Wood Revere Copper & Brass, Inc.	Paul F. Russo Bendix Aviation Corp.	Catherine Hock	Andrew H. Nash US Naval Gun Factory
Washington	S. J. Lorber	Elbert Magruder	Carol O. Baumann Monsanto Chemical Co.	George G. Rice
W. Massachusetts	John D. Hinchen Monsanto Chemical Co.	Joseph G. Griffin Westinghouse Electric Co.	Warren G. Lyman	Max D. Eaton
Wichita	Robert W. Watson	Vida G. Hildyard Boeing Airplane Co.	C. E. Laforet	James McMillan
Windsor	M. Fred Kennedy	George A. Dowling	Edward Schuch Fairmont Foods Co.	Paul A. Ebert Kohler Co.
Winnebago	Elvin G. Powell Marathon Corp.	Leland J. Manders Charmin Paper Mills, Inc.	Joseph F. Drozd General Electric Co.	Alexander C. Cirillo Chicago Pneumatic Co.
Worcester	Arthur P. Pingalore General Electric Co.	Warren D. Arnold, Jr. Draper Corp.	P. Roy Leaman Bay State Abrasive Products Co.	Francis B. Olson Norton Co.
Youngstown	David J. Ausmus Joy Mfg. Co.	Frank Jayne Trumbull Lamp Works	Charles K. Cooper Packard Electric Div.	William J. Cain Republic Steel Corp.

Dr. M. E. Mundel of Marquette University will deliver the keynote talk on a phase of the contribution of statistics in the field of industrial engineering. He is a recognized authority in the field and will certainly give us a challenging discussion.

One of the luncheons will take up the subject, "SQC—past, present, and future" which any 10th anniversary meeting should do. In this case it will be done by such experienced and sincere members of the quality control profession as Major General Leslie E. Simon, Assistant Chief of Ordnance; Arthur Bender, Jr., President of the Society; Fred Halton, Jr., Chairman, Midwest Conference Board; and Warren E. Jones, management consultant. All of these persons are extremely well qualified to speak on the subject because they have pioneered in practice to as great a degree as others have pioneered in education.

The other luncheon will be sparked by one of those remarkably fine inspirational talks for which quality control conferences are becoming famous. The speaker this time is Dr. J. Martin Klotsche, President, Wisconsin State College, Milwaukee who will talk on "The Destiny That Is Ours."

The word "Gemuetlichkeit" in Milwaukee means good fellowship. On Wednesday, Nov. 16, before the conference, the early arrivals may gather again at the Pabst Blue Ribbon Hall in an old world atmosphere conducive to just the right degree of gaiety that goes with welcoming friends who haven't met for many months. On Thursday evening, in the ballroom of the Hotel Schroeder, there will be a party to celebrate the 10th anniversary of the Midwest Conference. There will have to be a charge of $1.00 per person to help defray some of the expense but there will be music, entertainment, and dancing after the show. The attendance will not be limited to conference registrants because we want you to bring your friends to help us celebrate.

This is a conference that you cannot afford to miss. If you haven't received your program, write to Dale A. Cue, A. O. Smith Corp., Milwaukee 1, Wisconsin.

PITTSFIELD The executive committee discussed plans for two courses in quality control. An intermediate course will be given to supplement the elementary course given two years ago. In addition a seminar on advanced subjects will be given for a small group.

RHODE ISLAND Our Messrs. R. Shaw Goldthwait and William P. Hammerly, treasurer and registration chairman respectively, of the Ninth New England quality control conference to be held in Hartford on Nov. 3-5 reported that the program is completed and announcements will soon be mailed. Anyone not on the New England mailing list who is interested in attending should write to Mr. Hammerly at Pantex Mfg. Corp., Pawtucket, R. I.

SAN BERNARDINO Through the efforts of Glen Ghormley, educational committee chairman, the Extension Div., University of California, will offer two evening courses in quality control at Chaffey College, Ontario, starting this fall. Running concurrently, the second and third semesters of a comprehensive four semester course will be offered for college credit.

William A. Goddard, quality control engineer of Kwik-Set Locks, Inc., Anaheim, will conduct an elementary course in quality control and inspection methods under the sponsorship of the Anaheim Industrial Group at Anaheim High School. The Anaheim Industrial Group is an organization of industrial executives in that area, organized to promote various adult industrial training programs through the public school system.

SOUTHERN CONNECTICUT Ralph Minervino, quality control manager of Perma-O-Last, Waterbury, has been named as a member of the arrangement committee for the coming Ninth New England Conference to be held at the Hotel Statler, Hartford on Nov. 3-5. The section is one of the sponsoring sections of the conference and a large turnout is expected to be in attendance from the section.

SYRACUSE In conjunction with H. W. Smith Technical and Industrial High School of Syracuse, N. Y., the section is sponsoring three courses in applied quality control ranging from basic to advanced quality control. There are 15 sessions, the first of which began the later part of September. All classes will be taught by members of the section.

WESTERN MASSACHUSETTS The intermediate course to be sponsored by this section is not definitely set for the time of starting but it is expected now that it will be sometime during the last ten days of October. Notification will be given to newspapers, members and prospective students in ample time so that all who are interested in taking the course will be notified in advance.

WORCESTER Mr. Francis Olson, Norton Co., Worcester, is in charge of the exhibits for the Ninth New England Conference which will be held at the Statler Hotel, Hartford, Conn. on Nov. 3-5.

NINTH NEW ENGLAND CONFERENCE The Ninth New England Conference will be held at the Hotel Statler, Hartford, Conn. on Nov. 3-5. A well rounded program of clinical sessions has been arranged, with excellent speakers, based on the conference theme, "Quality control is good insurance." A full day of management seminars is included in the program. These are under the leadership of such capable personalities as Dr. Juran, Leonard Seder, Dorian Shainin, William J. Masser, and Ralph E. Wareham.

There will be five general classifications of industries covered in the clinical sessions. They are: metal processes, special processes (insurance and administrative applications), continuous processes, aircraft and electronics, and general.

In the heavily industrialized New England area this conference presents an excellent opportunity to become

Sixth Annual Textile
Quality Control Conference
February 13-15
Charlottesville, Virginia

The reverse side of the 1955-56 membership card carries the incorrect date and place at which the Sixth Annual Textile Quality Control Conference is to be held. The conference is to be held February 13-15, 1956 at The Institute of Textile Technology, Charlottesville, Va.

better acquainted with this latest tool of management. Further information may be had by contacting W. P. Hammerly, Conference Registrar Chairman, at the Pantex Manufacturing Corp., Pawtucket, R. I.

UCLA EXTENSION ENGINEERING AND MANAGEMENT COURSE The University of California Extension and the College of Engineering and School of Business Administration will offer an engineering and management course from Jan. 23 to Feb. 2, 1956.

Inaugurated at UCLA last January, the program, first of its kind to offer instruction in both the traditional and the new areas of industrial engineering and management theory and practice, brought executives, managers and supervisors, from firms throughout the US, Canada and the Hawaiian Islands to the Los Angeles campus.

The ten-day course includes twenty offering general management subjects, traditional industrial engineerning, automation and electronic data processing for business and industry, so that each participant may choose a program tailored to his own needs to improve his current job performance, prepare him for a new assignment, or supplement his company's training program.

Information folders and application blanks are available on request to Mr. Edward P. Coleman, coordinator, College of Engineering, University of California, Los Angeles 24, Calif.

ALL-DAY CLINIC NOVEMBER 4 The Chattanooga, Tennessee, Birmingham, and Huntsville sections, in conjunction with the Chemical and Textile divisions, are sponsoring an all-day clinic to be held at the Hotel Patten, Chattanooga, Tenn., Friday, Nov. 4.

The clinic aims to spread the latest ideas of quality control among the uninitiated in this area. One of the series is basically educational; the second series is aimed at applications in textile, paper and foundry industries with a dash of engineering and experimental design plus setting work standards. The human side is handled by two presentations covering the importance of the operator and the liaison among worker supervision and management. Mr. Charles A. Bicking is the guest speaker, his subject being "Management Views of Quality Control."

Tentative plans are underway to have a "meet your speaker night" on Thursday, Nov. 3; an informal social function to which all would be invited for a nominal fee to cover refreshments.

The last such conference in this area was the Southern Conference, held a year ago, at which time close to 200 people were present. With this year's excellent program, the committee expects that this figure will easily be topped.

Further information may be obtained by writing to Mr. Gerald Chastain, Du Pont Nylon Plant, Chattanooga, Tenn.

"FOR MANY ARE CALLED, BUT FEW ARE . . ."

ALBANY Officers elected for the 55-56 season are: President, C. D. Ferris, Mohawk Carpet Co.; Vice President, D. Maynard Wells, General Electric Co.; Secretary, R. W. Mapes, Behr-Manning, Div. of Norton Co.; Treasurer, Miss Nura Turner, New York State College for Teachers.

BALTIMORE Several changes in our officers for the new season have come up. These are as follows: the new Vice Chairman of the section is W. J. Aring; the new Secretary to succeed Mr. Aring is J. W. Shipley.

DANVILLE -SUNBURY Due to the resignation of Frank Honicker, Fred Bernstine has assumed the responsibilities of section chairman. At a meeting of the executive committee held in August, section secretary J. Harold Backenstoe was elected to the Vice Chairmanship. Filling in for Harold as secretary will be Jim Rohland.

GREATER MUSKEGON Officers for the 1955-56 season are: Chairman, Glenn A. Bailey, American Coil Spring Co.; Vice Chairman, Chas. C. Duff, Anaconda Wire & Cable Co.; Secretary, Ray L. Porter, Muskegon Piston Ring Co.; Treasurer, C. R. Wainwright, Sealed Power Corp.

MILWAUKEE Officers of the Milwaukee Section for the coming year are as follows: Chairman, A. E. Jakel, Quality Control Consultant; Vice Chairman, G. I. Craycraft, The Midland Co.; Secretary, L. A. Neuman, Miller Brewing Co.; Treasurer, C. P. Dewus, International Harvester Co.

NEW HAMPSHIRE The section has elected the following officers for the coming year: Chairman, Wesley S. Gahagan, General Electric Co., Somersworth; Vice Chairman, Charles A. Currier, Scott & Williams, Inc., Laconia; Secretary-Treasurer, Carl A. Laurier, Scott & Williams, Inc., Laconia.

PHILADELPHIA Elected officers for 55-56 are: Andy Irvine, Campbell Soup, Chairman; Stan Wirtschafter, I.T.E. Circuit Breaker, Vice Chairman; Gordon Beckhart, R.C.A., Secretary; Jim Crotty, Crown Can Co., Treasurer; Dick Jacobs, R.C.A., Editor.

PITTSFIELD The section elected the following officers for the 1955-56 season: F. C. Hartwell, Chairman, Peter J. Schweitzer, Inc.; G. E. Lyman, Vice Chairman, Peter J. Schweitzer, Inc.; T. Sargent, Secretary, Crane & Co.; W. Dodd, Treasurer, General Electric Co.

The newly elected Treasurer, Mr. William Dodd of General Electric, was transferred to General Electric's air-conditioning plant in New Jersey. Dr. Lawrence Spooner of General Electric has been elected to fill the post of Treasurer.

ROCHESTER Elected officers for 1955-56 are: President, Cuyler J. Hawkes; Vice President, Hubert C. Minard; Secretary-Treasurer, Elmer Lalonde; Executive Secretary, Russell C. McCarthy.

SYRACUSE The officers who were installed at a recent dinner meeting held at the popular Martin's Restaurant are: Chairman, Robert Hofstead; Vice Chairman, Richard Holmes; Secretary, George Endrich; Treasurer, Albert Edgar.

DIVISIONS

Chemical Division

On July 28, Chairman Harry Wehrly, Secretary D. H. Davis, and Treasurer Gene Yehle met at Midland, Mich. to review the present status of the division and formulate objectives for the coming year. Particular emphasis was given to district councilor activities and publication plans for Chemical Division News.

A meeting of all officers and district councilors was held Sept. 16 in Ann Arbor, Mich. The agenda for the meeting included officer's reports, subcommittee activities, budget and finance, by-laws, councilor duties, publications, nominations and elections, and division membership promotion.

The division welcomes the appointment of Clarence Burdick, National Executive Director, as trustee for the Chemical Division. It will be a pleasure to work with Clarence and his experience and guidance should prove of great value to our division.

We deeply regret the loss of Owen F. Keeler as our chairman of the Food Subcommittee. Owen is joining the Chrysler Corp. so the Chemical Division's loss will undoubtedly be the Automotive Division's gain. Doctor H. L. Stier, National Canners Assoc., will handle the affairs of the Food Subcommittee for the interim period until a new chairman is appointed.

MEMBERSHIP CORNER

The South Bend-Mishawaka (Indiana) Section in the one year of its existence has enjoyed a most satisfying growth. This growth is not due to any accident nor to any magic formula; but is a product of much planning, follow up, and in general a lot of hard work and the cooperation of many individuals.

The yield in membership from the year of activity is not yet completely realized. During the latter half of the 1954-1955 season, an intense educational program was launched. The termination of the classes were concurrant with the section's season activities and very few students made application for membership due to this nearness to the end of season activity. However, the benefits of enrollment of the members of the classes are now showing up in new member enrollment at the start of the 1955-1956 activity.

It is pleasantly surprising to note the general interest in the application of statistics to quality control that now exists in industrial communities as can be revealed by a well advertized educational program. The response to the announcement of such a program in the South Bend-Mishawaka area was much greater than contemplated and it was necessary to reject a large number of applications on account of the limitations on facilities. The plans for the educational program for this season provide double the facilities of last year. In fact, many applications had been received in advance of any announcements of an educational program. It is expected that the yield in membership stimulated by the education program will be much greater than last year.

A wisely conducted educational program not only serves to increase membership but is probably the best known method to "create, promote, and stimulate interest." It can also be a source of revenue to promote other section activities.

SIGNIFICANT DIFFERENCES

Robert R. Jones, Albany section, recently left his position as quality supervisory of Bigelow Sanford and is now associated with the Wright Aeronautical Div., Curtis-Wright Corp, Wood Ridge, N. J.

Mr. George Cohan, deputy assistant for quality at Hill Air Base, has been selected as representative for the Salt Lake section on the Western Quality Control Council.

Mr. Ross Martin, Birmingham section, has accepted a position as plant manager of The Rich Manufacturing Co., Los Angeles, Calif.

Frank Honiker, Danville-Sunbury section, has accepted a position in the legal department of Smith, Kline, & French Laboratories in Philadelphia. Frank, who was a charter member and an active participant in the Society will remain a member of our section, although he has resigned as chairman. Frank was formerly a supervisor in the control section of Merck & Co., Danville.

From mid-September to the early part of November, Mr. Tom Kerr, Harrisburg section, quality manager, Automatic Machine Div., Aircraft-Marine Products, was on temporary duty with the European operations of Aircraft-Marine Products.

Robert E. Shmalberg, former officer of the Kansas City section has been transferred by Westinghouse Electric Corp. to Lima, Ohio, in the company's Small Motor Div. There, he is the supervisor of quality control of commercial products manufactured in the four plants that are a part of that division.

The following changes involving members of the Michigan section are announced. George Hawley has left the Ford Motor Co. to accept a position as quality control engineer for the Sandia Corp., Albuquerque, N. M. Ed Ford, McCord Corp., has been transferred from Detroit to become quality control manager of the company's Ohio plant. John Randall has left the Chevrolet Div. of General Motors Corp. to accept a position in the quality control dept. of Anheuser Busch in St. Louis, Mo.

Mr. Charles Baker, the elected Secretary-Treasurer of the Munice Section has been promoted to the position of customer contacts in the Detroit area by the Warner Gear Div., Borg-Warner Corp. His vacated post as Secretary-Treasurer will be ably filled by Clarence Harman, who served in this same capacity for the year 1952-53.

L. A. Erickson, Northeastern Indiana membership chairman, announces that all members of his committee will act as contact men to maintain constant liaison with individual members and will collect dues from such members who have, through one cause or another, neglected to do so and contact all former members for reinstatement. His activities will also be extended to contacting heads of industry throughout the Northeastern Indiana area for promoting increased activity and membership for 1955-56.

R. A. Snyder, chairman of the educational committee of the Northeastern Indiana section is to conduct a 15 minute session prior to the main feature of each regular meeting on "Things you should know."

The Philadelphia section announced the following changes in the status of a few of their members.

Phil McGrath was recently promoted and transferred to quality manager, West Coast Div., U.S. Pipe and Foundry Co.

Gordon Beckhart was promoted to reliability engineer, General Engineering, RCA.

Andy Irvine joined Campbell Soup Co., as QC supervisor, Can Div. He was formerly with the Electric Storage Battery Co., Philadelphia.

Fred Seitzinger, a winner in the 1954 paper writing contest held by the section, joined RCA as a computer systems engineer. This was a direct result of the paper he wrote on "Punching versus verifying in a punch card system." He was formerly a field engineer for IBM.

Another winner, Robert Klein, was promoted to manager, time study dept., Parts Div., RCA, when management became aware of what SQC can do for time study.

Dick Jacobs has been promoted to reliability engineer, Computer Systems Engineering, RCA.

Dr. Paul Doigan, past chairman and one of the Charter Members of the Pittsfield section, has been transferred to the Advanced Electronics Center, Cornell University, Ithaca, N. Y., by General Electric, where he will be connected with advanced degree recruiting. Dr. Doigan will be sorely missed by his associates on the executive committee as he has been very active in promoting the Pittsfield section and quality control.

The executive committee of the Rhode Island section has approved the adoption of a new constitution for the Rhode Island section. The new constitution more clearly states the duties of the officers and defines the responsibilities for the various committee chairmen. It will be presented to the membership in the near future for ratification.

Eugene V. Grumman, vice chairman of the Southern Connecticut section has been promoted to assistant works manager, Bullard Co., Bridgeport. Mr. Grumman had previously held the position of manager of quality control.

R. A. Lucas, director of the Toronto section, is again lecturing this year on quality control through statistical methods at the University of Toronto extension course which began Oct. 3.

The Milwaukee section notes with deepest regret the sudden passing of one of its members John J. Collopy. Mr. Collopy joined our section last year as a member grade member. He was employed by the Line Material Co., South Milwaukee, for 11 years, most recently as an inspection supervisor.

Douglass Potter (Metropolitan Section), Chief Inspector and Quality Control Engineer at the Thomas & Betts Co. in Elizabeth, N. J., died on August 24, 1955 after an illness that had kept him from his work since June 10, 1955. He was 65 years old.

Doug came to T & B as Chief Inspector in 1942. He joined the Metropolitan Section in 1950. Largely through his initiative and patient effort, his company now has a healthy, plant-wide SQC program actively supported by both management and operating personnel.

In addition to selling his own company on SQC, Doug and his staff have been instrumental in getting successful SQC operations adopted in the plants of several of T & B's suppliers, with mutual benefits to both these suppliers and T & B.

Bibliography

JOSEPH MOVSHIN, *Editor*

Assisted by the Editorial Committee, St. Louis Section, ASQC

On matters concerning the Bibliography Department, send correspondence, suggestions, and contributions to:

Joseph Movshin
9220 Old Bonhomme Road
St. Louis 24, Mo.

Selected references in the Bibliography of *Industrial Quality Control* are obtained from the following sources:

The international Statistical Institute, *International Journal of Abstracts on Statistical Methods in Industry.*

APPLICATION—
AIRCRAFT INDUSTRY

A STATISTICAL GUIDE FOR ACCIDENT RESEARCH, ILLUSTRATED BY APPLICATON TO NON-AIR-CARRIER FLYING, 1949-1951, by Acheson J. Duncan (Journal of the Operations Research Society of America—v. 3, n. 1, Feb. 1955 p. 77-90)

A rating index for use as a guide in non-air-carrier flying accident research has been developed to circumvent the special problem arising from lack of data on flying time in accident reports. An expected accident frequency rating has been developed from data obtained over a three year period. This data is based on aircraft types, types of accidents, phase of operation, and primary cause. The rating indices are plotted similar to control chart data, showing upper and lower control limits. The ratings of each plane are plotted horizontally in terms of the categories of the variable tested. It is emphasized that this process yields only relative ratings which can be used as guides for further research until

adequate flying time data become available. In addition to giving cautions familiar to experienced statisticians, the author stresses that the differences in plane use must be considered. The author also suggests that this technique can be used in other phases of aeronautics as well as in other fields.

APPLICATION— CHEMICAL INDUSTRY

APPLICATION OF STATISTICAL ANALYSIS TO ANALYTICAL DATA, by P. D. Lark (School of Applied Chemistry, The New South Wales University of Technology, Broadway, Sydney, N.S.W. Australia) (Analytical Chemistry — v. 26, 1954, p. 1712)

The principle of least squares provides a means of separating and estimating the systematic and random errors in determinations by an analytical method if it is investigated over a sufficient range of concentrations. The method of obtaining the estimates of error and interpreting them depends on the adoption of some suitable hypothesis about the relationship of the two types of error to the amount of substance being assayed. Unless this is done, tests of significance or statements involving probability may not be made. In the extended treatment of an example the necessary steps in a statistical examination—choice of hypothesis, computation of regression equations and associated errors, and testing for rejection of suspected values—are illustrated. The results of such an examination are applied to the predictions of the true amount of substance in a sample from that found by chemical analysis.

A PLAN FOR STUDYING THE ACCURACY AND PRECISION OF AN ANALYTICAL PROCEDURE, by Frederic J. Linnig, John Mandel, and Jean M. Peterson (National Bureau of Standards, Washington, D. C.) (Analytical Chemistry — v. 26, 1954, p. 1102)

This work was undertaken to clarify the concepts of accuracy and precision and to show how statistical methods available in the literature may be used in the flexible plan for studying the accuracy and precision of an analytical procedure. The plan, illustrated by application to a particular analytical method, involves the segregation of relative-type and constant-type systematic errors. The effect of relative-type errors is generally more important in the determination of major components, while constant type errors are more serious in the determination of trace components of material. Methods are presented for detecting the sources of variability in the results which reduce the precision of an analytical procedure. The relationship between the concepts of accuracy and precision of a method is shown to depend on the particular application involved. Methods having no satisfactory theoretical basis may be studied using these techniques and maximum efficiency may be achieved in the study by designing the experimental work to fit the particular problem in hand. Segregation of errors and detection of sources of variability facilitate their elimination or control and lead to a more realistic estimate of the limitations of the method. The segregated relative-type and constant-type errors may be helpful in the quantitative

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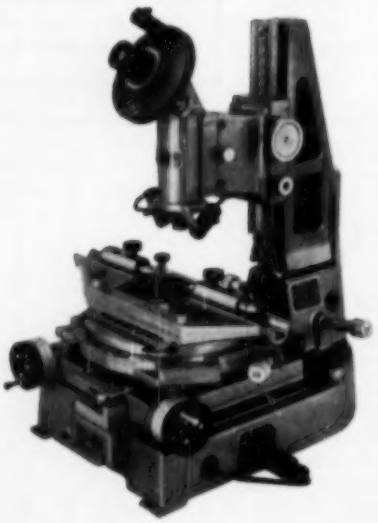

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study of the chemical factors involved in some equilibrium reactions.

APPLICATION—
MEDICAL & DRUG INDUSTRY

ASSAY OF PREPARATIONS OF VERATRUM VIRIDE BY HYPOTENSIVE ACTIVITY IN DOGS, by Graham Chen and David Russell (Parke, Davis and Co., Detroit, Michigan)
(Journal of American Pharmaceutical Association—v. 42, 1953, p. 373)

A procedure is presented for estimating the hypotensive activity of veratrum preparations in dogs. Through the analysis of variance, the accuracy of the method is shown to be within the limits of variation in biological assays of ± 10 percent.

COMPRESSED TABLETS—WEIGHT VARIATION, by Angel S. Arambulo, Helena Suen Fu, and Dwight L. Deardorff (Department of Pharmacy, College of Pharmacy, University of Illinois, Chicago)
(Journal of American Pharmaceutical Association—v. 42, 1953, p. 692)

The effect of granulation particle size on the weight variation of compressed tablets was studied, using statistical quality control procedures. As the particle size decreased the tablet weight variation decreased, passed through a minimum at 400-800 microns and then increased.

A TASTE PANEL STUDY OF CYCLAMATE - SACCHARIN MIXTURE AND ITS COMPONENTS, by Hugh C. Vincent, Matthew J. Lynch, Florence M. Pheley, Fred J. Melgren, and F. J. Kirchmeyer (Abbott Laboratories, North Chicago, Illinois)
(Journal of the American Pharmaceutical Association—v. 44, n. 7, July 1955, p. 442-446)

Taste panel techniques were used to study the relative sweetness and the incidence of off-taste in solutions of cyclamate, of saccharin, and of their 10:1 mixture.

This study made use of a balanced incomplete block design of experiment, from Cochran and Cox, "Experimental Designs."

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Ranked means, and the t-test were used. Least squares regression lines were calculated.

APPLICATION—MISCELLANEOUS

EFFECT OF SAMPLE PREPARATION ON PRECISION IN THE HIDE SUBSTANCE DETERMINATION, by Sverre Dahl (National Bureau of Standards) (Journal American Leather Chemists' Association—v. 49, n. 7, July 1954, p. 515)

The precision of hide substance determinations by the Kjeldahl method is improved by additional grinding and mixing, but not by increasing the specimen size from 0.5 grams to 1.5 grams. This conclusion is based on a statistically designed, factorial experiment involving four sample-preparations and two sample-sizes with 16 replicates per cell. Analysis of variance was carried out on the averages as well as the within-cell standard deviations, and the study covers both precision and accuracy.

QUALITY CONTROL, by Charles W. Fizzell (Corona Brewing Corp., San Juan, Puerto Rico) (American Brewer—v. 88, n. 4, Apr. 1955, p. 37-38)

The organization of a quality control program, particularly suitable for the smaller brewery, is discussed by a brewmaster under the heading "(1) control and (4) clinic control." A feature of the program is a "control room" which includes a control panel and control charts designed to present "what has been going on, what is going on and what should be going on." As an illustration, charts maintained on the original gravity of wort are discussed.

HOW TO MAKE UP CONTROL CHARTS FOR AUTOMATIC PROCESSES, by John K. Rudd (Richardson Scale Co. Clifton, N. J.)

(The Brewers Digest—v. 30, n. 4, Apr. 1955, p. 62-64, 67-88)

Elementary probability theory and its application to the control chart is discussed with an illustration of the average and range chart for an automatic scale.

AGING CHARACTERISTICS OF SIDE LEATHER, by W. T. Roddy and J. J. Jansing (Tanner's Council Research Laboratory, University of Cincinnati)

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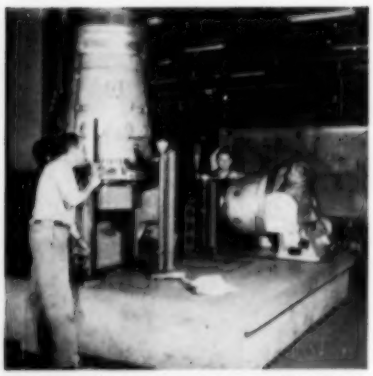

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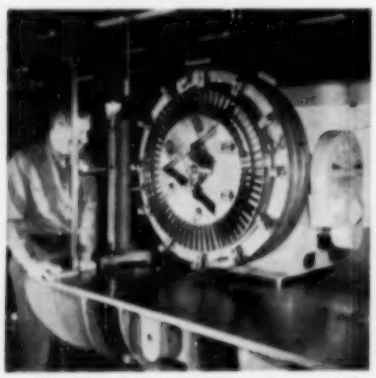

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(Journal American Leather Chemists' Association—v. 49, n. 12, Dec. 1954, p. 773)

A study was made on three types of leather to determine the changes in physical and chemical properties upon aging at three temperatures. The effect of aging on the various properties is evaluated by applying "Student's t" to aged versus control specimens.

CORRELATION

THE RANK CORRELATION METHODS, by John T. Litchfield, Jr., and Frank Wilcoxon (Stamford Research Laboratories and Lederle Laboratories Division, American Cyanamid Company, Stamford Connecticut, and Pearl River, N. Y.)
(Analytical Chemistry — v. 27, 1955, p. 299)

The usefulness of the rank correlation method has been increased by providing a table of critical totals for two levels of probability and a nomograph which gives the rank correlation coefficient directly. Use of the method is illustrated.

INDUSTRIAL MANAGEMENT

OPERATIONAL ACCOUNTING AND OPERATIONS RESEARCH
(Journal of Accountancy — Feb. 1955, p. 33-39)

Accounting systems when examined in the light of some of the concepts of operations research must be altered from their present forms. Operations research gives rise to a concept of operational accounting which can provide some of the information needed for the new scientific business approach.

THE ANSWER: LINEAR PROGRAMMING
(Business Week—Mar. 12, 1955, p. 43, 44)

Linear programming is described as a mathematical way of evaluating various possible courses of action to determine which is most desirable for a given goal. This approach is described as a new tool of management for decision making.

OPTIMAL ESTIMATION OF EXECUTIVE COMPENSATION BY LINEAR PROGRAMMING, by A. Charnes and W. W. Cooper (Carnegie Institute of Technology) and R. O. Ferguson (Methods Engineering Council)
(Management Science—Jan. 1955, p. 138, 151)

This article discusses the establishment of a linear programming relationship for various factors which may be considered as influencing executive compensation. Factors influencing salary include initiative, experience, sales quota and break even analysis, as well as general market value of the work. A formula is developed which must be considered subject to the existing policy and relative positions as they exist.

AN OPERATIONS RESEARCH PROGRAM FOR A RETAIL STORE CHAIN, by John F. Magee (Arthur D. Little, Inc. Cambridge, Mass.)
(Advanced Management — June 1955, p. 18, 21)

This article discusses in general terms the purpose and functioning of a research team using operations research techniques. The purpose of the team and the program is to secure information and new perspectives on older factors to provide guides for management and management decisions.

MISCELLANEOUS

MATHEMATICAL PROGRAMMING OF PORTFOLIO SELECTIONS, by A. D. Martin, Jr., (Carnegie Institute of Technology.)
(Management Science—Jan. 1955, p. 152, 166)

This article describes a method whereby an investor can maximize rate of return for a given series of investments for any predetermined risk. Variances and co-variances are used in considering the degree of risk and the possibilities of securities varying together in their rates of return. The author points out that these variances and co-variances are not usually known but suggests that they can be estimated on past performance of the securities. An example of this approach is given.

(Continued from page 1)

in the hole. The positive centralization of this series of gages is the result of a new design concept which produces a degree of centralizing that eliminates the necessity for careful alignment of the gage. An advantage of the concentricity of the centralizing contacts with the sensitive gaging contacts is that the gage can be accurately set without master rings if desired. Transfer accuracy between flat gage blocks and the radiused surface of the hole is better than 50 millionths of an inch. Wear is reduced by the use of large contact surfaces of the centralizer, the jewel bearings which support components of the gage head, plus Tungsten Carbide gaging contacts. Four gages in this series cover all requirements for checking hole diameters between ½ and eight inches with the maximum size for each gage being twice its minimum.

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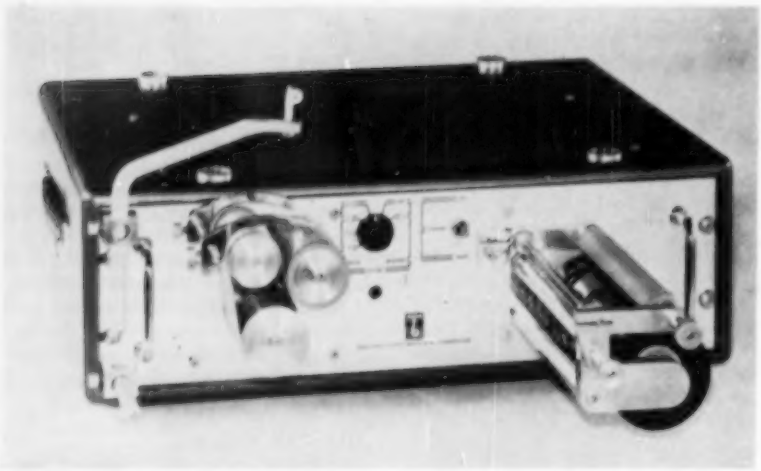

Brush Electronics Co., 3405 Perkins Ave., Cleveland 14, Ohio, have recently made available a combination material drive and yarn rewind for running test lengths of yarns, sliver or roving. The model BL-853 is a combination of the two individual units which Brush previously produced. The unit may be used with the Brush Uniformity Analyzer or similar electronic evenness testing equipment to drive test lengths and to rewind them. The rewind feature of the instrument is desirable where the same length is to be retested for the establishment of an average. It operates at a constant five ft. per second. The Material Drive unit will feed the material at one of four pre-selected speeds determined by the operator. The speeds are 0.5, 1.5, 5.0, or 15.0 feet per second. Rack mounting and portable cases are available for the unit.

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Development of a new metallurgical microscope with several design innovations was recently announced by the **Bausch & Lomb Optical Co.**, Rochester, N. Y. New features include a larger focusing stage with interchangeable stage plates which adapt it quickly for work with either transparent or opaque specimens; a fine-adjustment focusing knob located at table level and an accessory lens for concentrating external illumination into the microscope for photomicrographic use. The vertical illuminator and triple-revolving objective turret enable examinations of specimens to be made faster. Vertical illumination for the microscope is supplied through a true aperture diaphram illuminator that provides uniform lighting of the entire field. The reflecting unit, coated on both surfaces, provides oblique illumination for specialized applications. A supplementary lens designed to concentrate illumination from outside sources is available. The lens permits external light sources to be moved as much as seven inches from the microscope during photo-micrography. Also available for increased operating efficiency is a Bausch & Lomb Trivert illuminator that makes possible the study of opaque or semi-opaque specimens in bright field, dark field, or polarized light. The microscope is available in two models, one with monocular body, the other with binocular body. Detailed description of both models is available in bulletin D-1053 available from the manufacturer.

★ ★ ★

A new leak detector announced by **Beckman Division of Beckman Instruments, Inc.**, Fullerton 1, Calif. operates on the radio-frequency mass spectrometer principle. The new design results in a smaller more compact unit and provides working space on the counter top of the cabinet. To simplify maintenance, plug-in chasis have been utilized. The unit incorporates both audible and visible warning and will measure leak rates of one part in 700,000. Applications are found in the manufacture of refrigeration and air conditioning equipment, cathode ray tubes, transformer casings, and wherever high-vacuum systems, pressure systems or hermetic seals are used.

★ ★ ★

An acceleration testing machine that tests and calibrates small assemblies while subjecting them to multiples of the acceleration of gravity has recently been developed by **Schaevitz Machine Works,** Camden 1, N. J. The accelerator is capable of subjecting objects as large as a 5 inch cube weighing a maximum of three pounds to accelerations up to 250 G's. The rotating table is tapped with groups of holes to permit mounting, testing and calibrating four objects simultaneously. A speed range up to 1000 rpm is obtainable with precise electronic speed control. Eight instrument slip rings are provided for electrical connections between rotating test objects, stationary instruments and power sources. The column assembly, motor mount, rotating table, tachometer generator and rpm pickup are installed in a fabricated steel test stand with an integral ¼ inch thick steel plate safety guard enclosing the rotating table. The lid over the table is made of transparent ½ inch thick plexiglas which permits observation of the table top while providing protection for the operator. Dynamic braking is provided to bring the rotating table to a rapid stop. Single and four line pressure and vacuum systems are available if desired.

★ ★ ★

A new Microwave Frequency Standard for the accurate (0.001 percent) measurement of frequency from 2400 to 40,000 mc has been announced by the **Narda Corp.,** Mineola, Long Island, N. Y. The standard consists of a temperature stabilized crystal oscillator followed by a multiplier-amplifier chain, with outputs at 100, 500, and 1500 mc. The unit is supplied complete with sweep circuits for use with reflex klystron local oscillators to obtain beats with harmonics of the Standard output. Waveguide set-ups are supplied for the frequency ranges specified by the customer. These set-ups include a harmonic mixer for multiplying the Standard signal and mixing with the klystron output, frequency meter, directional coupler, two variable pads, termination, detector, and coaxial adapter when required. The harmonic mixer is the only mixer specifically designed for multiplying a standard crystal controlled signal for frequency measurement. The waveguide components are all available individually if the customer wishes to make use of equipment now in his possession. Besides the basic package and the waveguide components, the customer will require a video amplifier, a shortwave receiver, and an oscilloscope.

★ ★ ★

The new 70mm photo-fluorographic film viewers for mass radiography have been announced by the **Industrial Camera Division of Fairchild Camera and Instrument Corp.,** Syosset, N. Y. Used in mass photoradiography, the viewers will permit the reading of a large number of negatives over a long period of time while reducing eye fatigue to a minimum. Two models are available, one for viewing roll film, the other for cut film. The roll film viewer will handle any length of 70mm film from 10 inch to 100 feet. The cut film viewer will handle 70mm, 4 x 4 inch and 4 x 5 inch cut film. Two diameter magnification without distortion is provided by a set of two lenses, set $^{5}/_{32}$ inches apart. The lenses are sealed to prevent dust or dirt from entering. A circular fluorescent light to provide even illumination is housed in the base. The lamp and reflector are positioned so that only reflected light comes through the clear glass screen. In any viewing position the observer looks at reflected light only and never directly into the lamp. This is one of the features that helps to minimize eye-fatigue. Viewers will be available through all major x-ray manufacturers and their branch offices and distributors.

★ ★ ★

New Literature

The operation and uses of several Richardson Automatic Mill Grain Scales are described in a new data sheet offered by Richardson Scale Co., Clifton, N. J. This type scale is used to weigh grain from storage to the grinding mill or in process and has a reported accuracy of $^{1}/_{10}$ of one percent. A schematic drawing of the scale in operation in a typical mill installation is included. Hopper capacities, hourly weighing capacities, key dimensions and approximate shipping weights for the five different models are given.

A new catalog is available on request from the L. S. Starrett Co., Athol, Mass. Bulletin #416 illustrates the Starret line of dial indicators, dial gages and instruments.

Technical Charts, Inc., 189 Van Rensselaer Street, Buffalo 10, N. Y. has just published a compilation of bulletins featuring specifications for special recording charts to be used by instrument people when designing their own recording instruments. Included are 16 different bulletins describing specifications for chart papers, special recording papers, including heat sensitive and electro sensitive papers, roll chart core sizes, roll chart punch sizes and others.

The United States Testing Co., Inc., 1415 Park Avenue, Hoboken, N. J. announces publication of a new booklet entitled "Selected Scientific and Engineering Tables and Data." Issued in commemoration of the company's 75th anniversary, the booklet is composed of many kinds and types of technical information reflecting the many fields of activity of this diverse test-

ing organization. The 112 page paper-bound volume contains selected Chemical & Physical, Engineering, Plastics, Bacteriological, Leather, Psychometric and Textile tables and charts arranged for easy reference. The publication is available at no cost as a service of the United States Testing Co.

A new four page folder on the "Vidigage" Ultrasonic resonance thickness gage has been released by Branson Instruments, Inc., 430 Fairfield Avenue, Stamford, Conn. Operating principles, typical applications, and features are described in the folder.

A special report to foremen and supervisors on the recent ASQC convention held in New York is available from Elliott Service Co., 30 N. MacQuesten Parkway, Mount Vernon, N. Y. The Special Conference Report appeared in Management Information (1219 • 8-15-55) and until the supply is exhausted free copies will be sent at no cost or obligation.

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To better serve the members of the American Society for Quality Control who were unable to attend the New York Convention, the Society arranged for an over-run of the Convention Transactions. These Transactions are available from the New York office at a cost of $3.50 per copy. Due to the limited over-run, it will be necessary to fill these orders on a first-come first-served basis.

This volume is a gold mine of the latest developments and thinking in quality control. The table of contents below gives the great variety of subjects covered by these papers.

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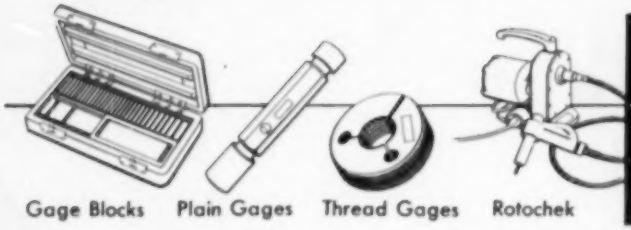

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